TECHNOLOGY DEPT.

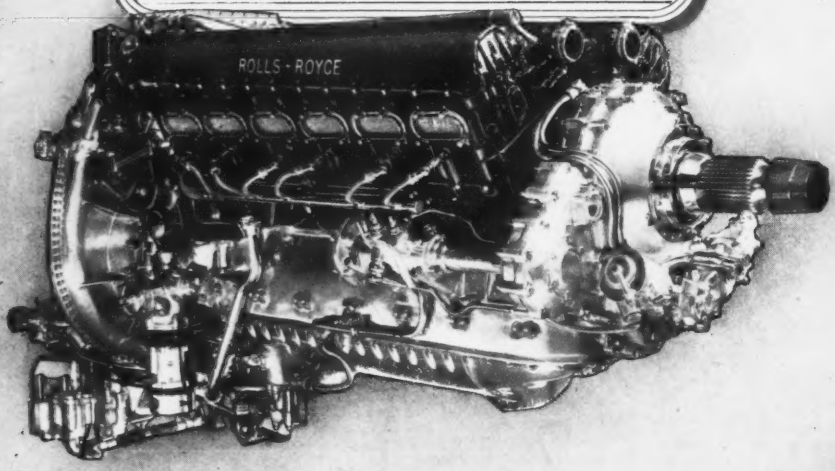
PUBLIC LIBRARY
FEB 1
DETROIT

JANUARY 1945
NO. 409 VOL. 49
SEVEN SHILLINGS
AND SIXPENCE

The Journal of THE ROYAL AERONAUTICAL SOCIETY

AIR SUPREMACY

MERLIN



The air supremacy of the Allies is one of the major factors contributing to ultimate victory.

In this air supremacy must be recognised the vital contribution made throughout the war by operational aircraft powered with Rolls-Royce engines.

HURRICANE	SPITFIRE	DEFIANT
BEAUFIGHTER	FULMAR	SEAFIRE
MUSTANG	BATTLE	WHITLEY
WELLINGTON	HALIFAX	LANCASTER
MOSQUITO		BARRACUDA

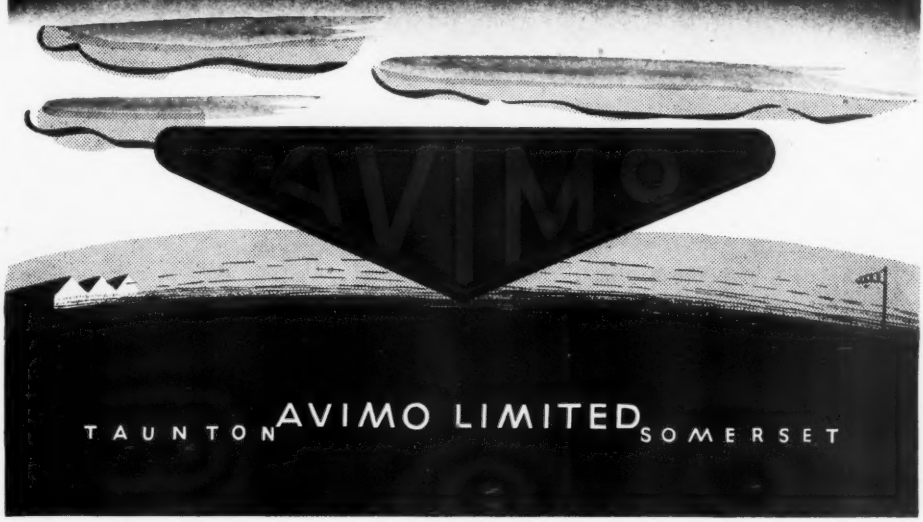
ROLLS-ROYCE

AERO ENGINES

Progress by Quality

TODAY IS TOMORROW

Today's experience is tomorrow's gain and in the 'Morrow' the post-war design and manufacture of Avimo Optical - Mechanical - Electrical Instruments and Aircraft Equipment will incorporate all the tremendous wartime developments.



TAUNTON AVIMO LIMITED SOMERSET

APPROVED UNDER AIR NAVIGATION RULES FOR CIVIL AVIATION

Braking records in the laboratory . . .

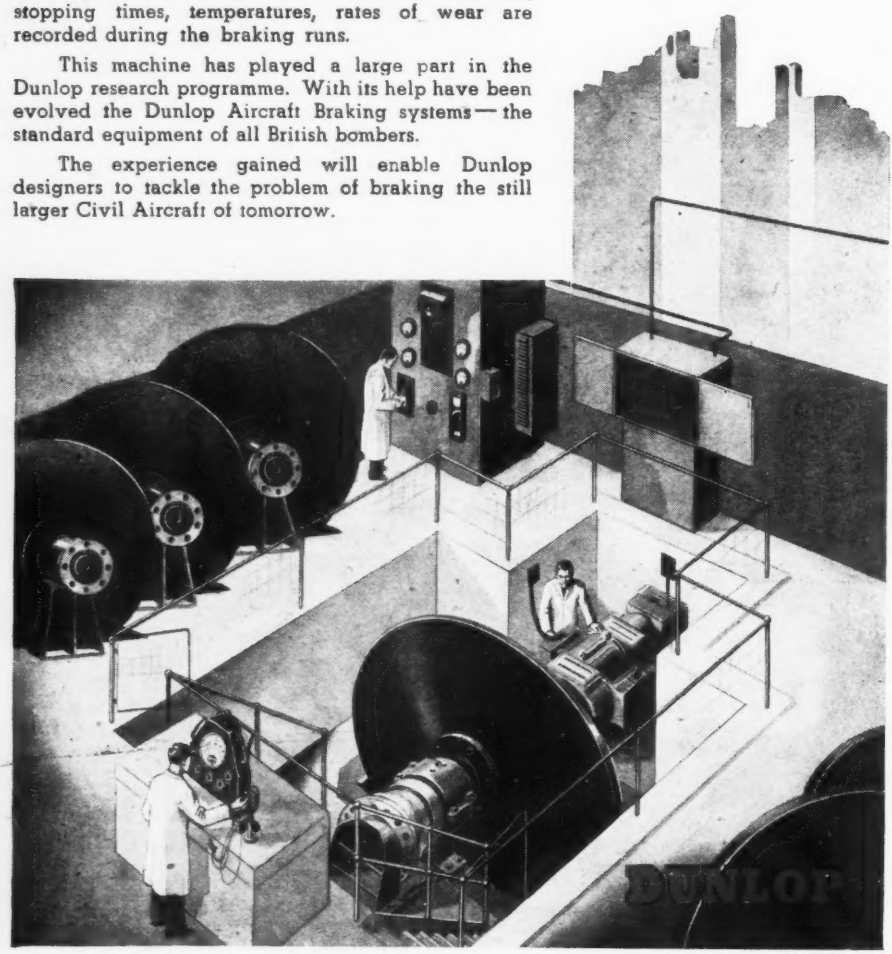
Dunlop engineers have evolved a testing machine, whereby the braking systems of the heaviest aircraft can be tried out in the laboratory under the most arduous working conditions.

The illustration shows a range of fly wheels, one of which is fitted to the test machine, depending upon the size of brake to be tested. By using the largest size the kinetic energy (40,000,000 ft. lb.) of an aeroplane weighing approximately 53 tons and landing at speeds up to 100 m.p.h. is reproduced.

Repeated 'landings' are made. Decelerations, stopping times, temperatures, rates of wear are recorded during the braking runs.

This machine has played a large part in the Dunlop research programme. With its help have been evolved the Dunlop Aircraft Braking systems — the standard equipment of all British bombers.

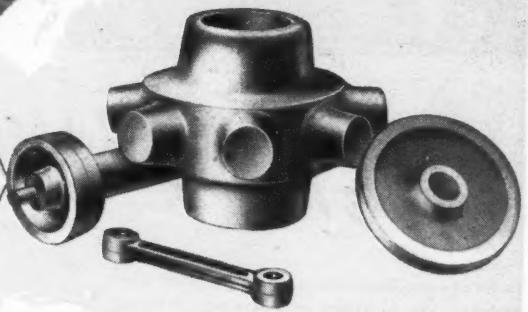
The experience gained will enable Dunlop designers to tackle the problem of braking the still larger Civil Aircraft of tomorrow.

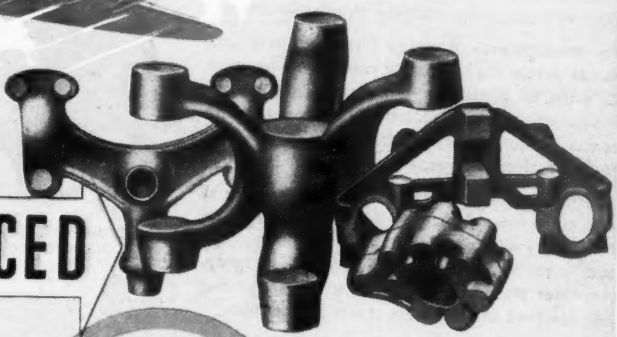


4H/610

DROP FORGINGS

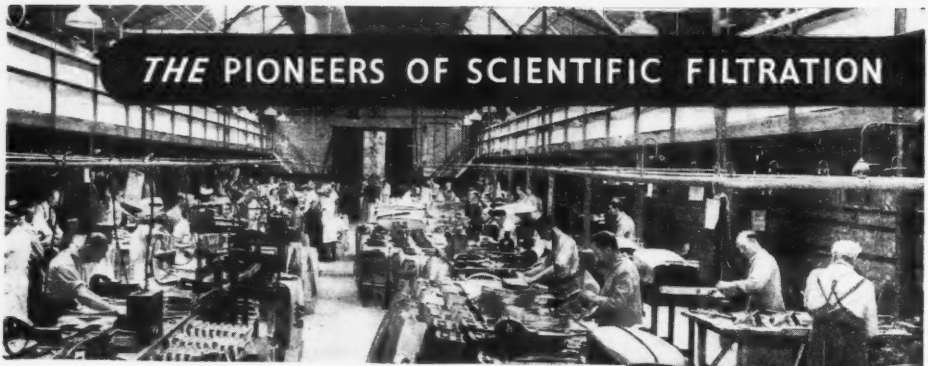
.... SIMPLE





OR ADVANCED

THE HUGHES-JOHNSON STAMPINGS LTD. LANGLEY GREEN
Nr. BIRMINGHAM.



As we have said before

really efficient filters are not mere gauze and fabric devices. We, of Vokes, who have won the reputation of producing the finest filters in the world, do not simply stitch together such materials and cut and fold the results into convenient shapes. Each type of filter is carefully designed for its particular job ; it is the consequence of successful research and experiment, and of a quarter-of-a-century's specialised manufacturing experience.

For instance, each of the air filters we have produced during the last twelve years for no less than 87 types of British and American aircraft ; each possessed its own separate problem, its own special requirements. Many filters had to be fitted to aircraft already in production.

The filter housing must prevent leakages and at the same time fit snugly into the cowling in conformity with the aircraft's general design. All such parts are taken care of ; the die-stamping, the sheet metal work involved, is all part of our job, designed and executed at our own Works.

You can trust the 99·9 per cent. efficiency of a Vokes' Filter. The Fighting Services do. Vokes manufacture over 3,000 models to meet all possible needs.

Two typical examples of the work turned out by Vokes

CONTRACTORS TO THE BRITISH AND DOMINION GOVERNMENTS.

VOKES LTD., LONDON, S.W

PIONEERS OF SCIENTIFIC FILTRATION

Designers, Manufacturers and Patentees of Air, Oil and Fuel Filters and of complete Cleaner Installations and Silencers.

BRANCHES

BELFAST	*Chairman :*	W. Browning, A.F.R.Ae.S., A.M.I.Mech.E.
	Hon. Secretary } *Treasurer* } *Librarian* }	W. H. Hambrook, A.F.R.Ae.S., Short & Harland, Ltd., Queen's Island, Belfast.
	Vice-Chairman :	R. Beaney, A.F.R.Ae.S., A.M.I.P.E.
	Committee :	H. G. Parker, A.F.R.Ae.S. —. Patrick. W. P. Kemp, M.I.P.E. W. H. W. Bell, A.F.R.Ae.S.
BIRMINGHAM	*Chairman :*	Capt. H. Nicolson, F.R.Ae.S.
	Hon. Secretary :	A. G. Strawford, A.R.Ae.S., 12, Cranmore Avenue, Handsworth, Birmingham, 21.
BRISTOL	*Chairman :*	W. R. Verdon Smith, B.C.L., M.A.(Oxon).
	Hon. Secretary :	S. G. Nash, A.F.R.Ae.S., Structural Research Laboratory, Bristol Aeroplane Co., Filton, Bristol.
	Hon. Treasurer :	R. N. Westaway.
	Committee :	A. C. Clinton, F.R.Ae.S. F. M. Owner, F.R.Ae.S. A. E. Russell, F.R.Ae.S. C. W. Tinson. Capt. C. F. Uwins, F.R.Ae.S.
BROUGH	*Chairman :*	G. E. Petty, F.R.Ae.S.
	Hon. Secretary :	D. R. Adams, A.F.R.Ae.S., Blackburn Aircraft, Ltd., Brough, E. Yorks.
	Treasurer :	S. J. Smyth, A.F.R.Ae.S.
	Committee :	G. B. Fenton, A.F.R.Ae.S. N. Biles. F. W. Buglass. J. White. V. S. Gaunt, A.F.R.Ae.S. S. M. Morison.
COVENTRY	*Chairman :*	H. M. Woodhams, O.B.E., A.F.R.Ae.S.
	Hon. Secretary (temp.) and Vice-Chairman :	E. D. Keen, A.F.R.Ae.S., "Brookhurst," Guys Cliff Avenue, Leamington Spa.
DERBY	*Chairman :*	A. G. Elliott, F.R.Ae.S.
	Vice-Chairmen :	L. F. R. Fell, F.R.Ae.S. A. A. Rubbra, F.R.Ae.S.
	Mins. Secretary :	C. L. Hinings, A.F.R.Ae.S.
	Hon. Secretary :	J. L. Batchelor, A.R.Ae.S., 154, Littleover Lane, Derby.
	Treasurer :	G. Parkin, A.F.R.Ae.S.
	Committee :	F. Nixon, F.R.Ae.S. F. E. Davis, A.R.Ae.S.
GLASGOW	*President :*	Major F. A. Bumpus, F.R.Ae.S.
	Chairman :	Robert McIntyre, A.F.R.Ae.S.
	Vice-Chairman :	G. F. P. Fox, A.F.R.Ae.S.
	Hon. Secretary :	D. Briant, A.R.Ae.S., 23, Thornwood Drive, Glasgow, W.1.
	Treasurer :	E. Loveless, A.F.R.Ae.S.
	Committee :	F. Kasy. F. W. Hopkins, A.F.R.Ae.S. —. Price. H. A. Craw, A.F.R.Ae.S. —. Newcombe. C. I. McBeth, A.R.Ae.S.

BRANCHES

GLOUCESTER AND CHELTENHAM	*Hon. Secretary :*	F. B. Ford, A.F.R.Ae.S., Kendon, Churchdown Lane, Hucclecote, Glos.
HATFIELD	*Chairman :*	C. C. Walker, F.R.Ae.S.
	Hon. Secretary :	H. W. L. Calder, A.R.Ae.S., de Havilland Aircraft Co., Ltd., Hatfield, Herts.
ISLE OF WIGHT	*Chairman :*	H. Knowler, F.R.Ae.S.
	Hon. Secretary :	M. J. Brennan, A.F.R.Ae.S., Aerodynamics Dept., Saunders-Roe, Ltd., Fryars, Beaumaris.
	Hon. Treasurer :	—. Thomson.
	Committee :	—. Bridges.
		J. C. Cooper.
		—. Longe.
		—. Stevenson.
		—. Brenton.
		—. Symons.
LUTON	*Chairman :*	A. A. Bage, F.R.Ae.S.
	Hon. Secretary :	S. A. Clark, A.R.Ae.S., c/o D. Napier & Son, Ltd., Luton, Beds.
MANCHESTER	*Chairman :*	R. Chadwick, C.B.E., M.Sc., F.R.Ae.S.
	Hon. Secretary :	J. A. E. Waterfall, 56, Manor Avenue, Ashton-on-Mersey, Cheshire.
	President :	T. O. M. Sopwith, C.B.E., F.R.Ae.S.
	Vice-Chairman :	Major T. M. Barlow, F.R.Ae.S.
	Committee :	H. Booth.
		H. T. Brooks.
		J. G. Cameron.
		R. H. Dobson, C.B.E., M.I.A.E., F.R.Ae.S.
		C. E. Fielding, O.B.E., A.F.R.Ae.S.
		C. A. Kaye.
		B. A. G. Meads.
		H. Rogerson, A.F.R.Ae.S.
MEDWAY	*Chairman :*	C. P. T. Lipscomb, F.R.Ae.S.
	Hon. Secretary :	J. W. Loader, B.Sc., A.F.R.Ae.S., 174, City Way, Rochester, Kent.
	Vice-Chairman :	J. L. Parker, F.R.Ae.S.
	Committee :	R. Boorman, A.F.R.Ae.S.
		J. H. Lower, A.F.R.Ae.S.
		J. W. Kenny, A.F.R.Ae.S.
		S. C. Hailey.
		G. A. Shirley.
		H. Linwood.
PORTSMOUTH	*Chairman :*	E. C. Green.
	Hon. Secretary :	D. H. Wilson, A.F.R.Ae.S., c/o Airspeed, Ltd., The Airport, Portsmouth.
	President :	A. Townsley.
	Vice-Chairman :	F. G. Boreham, A.F.R.Ae.S.
	Hon. Treasurer :	H. E. Bilney, F.I.A.C.
	Hon. Asst. Secretary :	A. G. Shove, A.F.R.Ae.S.
	Committee :	F. G. Banting.
		R. H. Bundy.
		D. G. Riches.
		G. A. G. Briggs.
		C. Hallett.
		F. J. Jupp, A.F.R.Ae.S.
	Hon Librarians :	J. A. Butcher, B.Sc.
		A. T. Visick, B.Sc.

BRANCHES

SOUTHAMPTON	*Chairman :*	S/Ldr. H. F. Jenkins.
	Hon. Secretary :	T. Tanner, A.F.R.Ae.S., University College, Southampton.
	Hon. Treasurer :	C. G. James.
	Committee :	B. G. Slater.
		H. White.
		—. Mace.
		L. Fowler.
		E. L. Cooper.
		W/Cmdr. T. R. Cave-Browne-Cave, F.R.Ae.S.
WEYBRIDGE	*Hon. Secretary :*	M. W. Wood, A.F.R.Ae.S., Vickers (Aviation), Ltd., Weybridge, Surrey.
	Committee :	D. L. Ellis, B.Sc., F.R.Ae.S.
		A. M. Edwards.
		H. H. Gardner, B.Sc., A.F.R.Ae.S.
		H. Jeffree, B.Sc., A.F.R.Ae.S.
		T. A. Kirkup.
		A. F. Walsh, A.F.R.Ae.S.
YEOVIL	*Chairman :*	E. Mensforth, M.A., M.I.M.E.
	Hon. Secretary :	L. A. Lansdown, A.F.R.Ae.S., Westland Aircraft, Ltd., Yeovil, Somerset
	Vice-Chairmen :	J. Fern, M.I.M.E.
		A. Davenport, F.R.Ae.S.
		E. Wheelden, M.I.P.E.
	Hon. Asst. Secretary :	A. Parkes, B.Sc., A.F.R.Ae.S.
	Committee :	R. B. Brigham, A.R.Ae.S.
		H. C. Harrison, A.F.R.Ae.S.
		—. Jewell.
		—. Pomeroy, M.B.E.
		—. Warren.
		W. M. Widgery, A.F.R.Ae.S.
		—. Quirk.

OVERSEAS

AUSTRALIA	*Hon. Secretary :*	J. B. Mills, B.Sc., A.F.R.Ae.S., Science House, Gloucester and Essex Street, Sydney, Australia.
CANADA		
	Montreal Aeronautical Section :	Engineering Institute of Canada, 2050, Mansfield Street, Montreal, Canada.
	Ottawa Aeronautic Section : Hon. Sec.:	M. S. Kuhring, A.R.Ae.S., National Research Council, Aeronautical Laboratory, Ottawa, Canada.
SOUTH AFRICA	*Chairman :*	Major R. A. Powell, A.F.R.Ae.S.
	Hon. Secretary :	Major D. A. Mann, A.F.R.Ae.S., P.O. Box 5944 Johannesburg, South Africa.

AN APPRECIATION

The Council of the Royal Aeronautical Society wish to thank the following Companies who, by their generous co-operation, have done so much to help in the production of the Journal in its new form.

ACCLES & POLLOCK LTD.

A&P
Make it with Tubes

AEROPLANE & MOTOR ALUMINIUM CASTINGS LTD.

AC-SPHINX SPARKING PLUG CO., LTD.

AIRSPEED LIMITED

AERASPRAY MFG. CO., LTD.

AERASPRAY

ALVIS LIMITED

"THE AEROPLANE"

THE AEROPLANE
TEMPLE PRESS Ltd.

GEORGE ANGUS & CO., LTD.

OIL GACO SEALS

ARMSTRONG SIDDELEY MOTORS LIMITED

ARMSTRONG SIDDELEY

BAKELITE LIMITED

TREFOIL

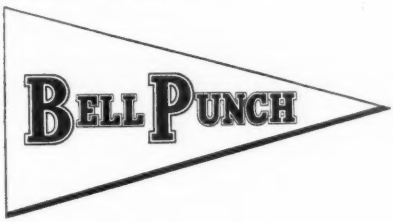
BAKELITE PLASTICS

REGD. TRADE MARKS

SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LTD.

SIR W. G.
ARMSTRONG WHITWORTH
AIRCRAFT LIMITED

BELL PUNCH COMPANY LTD.



THE AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO., LTD.

ELECTRICAL
TESTING
INSTRUMENTS

T. M. BIRKETT & SONS LTD.

NON-FERROUS CASTINGS
AND MACHINED PARTS

HANLEY - - STAFFS

AUTOMOTIVE PRODUCTS COMPANY LTD.

BIRMINGHAM ALUMINIUM CASTING (1903) CO., LTD.

AVIMO LIMITED

BLACKBURN AIRCRAFT LTD.

JAMES BOOTH & COMPANY LIMITED

STRONG LIGHT ALUMINIUM ALLOYS **DURALUMIN**

REGD. TRADE MARK

BRITISH ERMETO CORPORATION LTD.

ERMETO

BOULTON PAUL AIRCRAFT LTD.

AIRCRAFT & BPA ARMAMENTS

THE BRITISH PARACHUTE COMPANY LIMITED

THE BRISTOL AEROPLANE CO., LTD.

"Bristol"

BRITISH ROPES LIMITED

HEAD OFFICE: DONCASTER

THE BRITISH ALUMINIUM CO., LTD.

THE BRITISH THOMSON-HOUSTON CO., LIMITED

Magnetos and Electrical Equipment

THE BRITISH AVIATION INSURANCE COMPANY LTD.

BRITISH WIRE PRODUCTS LTD.

THE BROOKE TOOL MANUFACTURING CO., LIMITED

B.T.M.

BUTLERS LIMITED

BUTLERS LIMITED BIRMINGHAM THE SEAL OF QUALITY

BROOM & WADE LTD.

"BROOMWADE"

THE CHLORIDE ELECTRICAL STORAGE CO., LTD.

Exide

AIRCRAFT BATTERIES

BROWN BROTHERS (AIRCRAFT) LTD.

Brown Brothers (AIRCRAFT) Ltd.

CONTROL AEROJACKS, A.G.S. & A.S. PARTS

THE CLYDE ALLOY STEEL CO., LTD.

Clyde Alloy

DAVID BROWN & SONS (HUDDERSFIELD) LTD.

David Brown

COOPER & CO. (B'HAM), LIMITED

COOPERS

INDUSTRIAL FELT PRODUCTS

THE BUSHING COMPANY LIMITED

THE BUSHING CO. LTD.

TEXOLEX

REG.

HEBBURN ON TYNE

CROWN WELDING CO., LTD.

CROWN WELDING

DOUGLAS

THE DE HAVILLAND AIRCRAFT COMPANY LIMITED

DH

DUNFORD & ELLIOTT (SHEFFIELD) LTD.

Dunelt
Special steels
FOR AIRCRAFT

DE LA RUE INSULATION LTD.

De La Rue Insulation Ltd

DUNLOP RUBBER CO., LTD.

DUNLOP

DE LA RUE PLASTICS LTD.

De La Rue Plastics Ltd

THE FAIREY AVIATION COMPANY LTD.

FAIREY

DELCO-REMY & HYATT LTD.

ELECTRONIC
Delco
MOTORS

FERODO LIMITED

REGD. TRADE MARK
FERODO

DOWTY EQUIPMENT LIMITED

DOWTY
UNDERCARRIAGE AND
HYDRAULIC EQUIPMENT

THOS. FIRTH & JOHN BROWN LTD.

STEEL STEEL STEEL STEEL STEEL
STEEL STEEL STEEL STEEL STEEL
STEEL FIRTH-BROWN STEEL
STEEL STEEL
STEEL STEEL STEEL STEEL STEEL
STEEL STEEL STEEL STEEL STEEL
THOS FIRTH & JOHN BROWN LTD SHEFFIELD

FIRTH-VICKERS STAINLESS STEELS LTD.

GIRLING LIMITED

FLIGHT PUBLISHING CO., LIMITED

GLOSTER AIRCRAFT CO., LTD.

FLIGHT REFUELLING LTD.

FLIGHT REFUELLING LTD

GRAVINER MANUFACTURING COMPANY LTD.

FOLLAND AIRCRAFT LTD.

HAMBLE, SOUTHAMPTON

HANDLEY PAGE LTD.

GILLETT STEPHEN & CO., LTD.

MANUFACTURERS OF UNDERCARRIAGES AND HYDRAULICS FOR AIRCRAFT

HAWKER AIRCRAFT LTD.

HAWKER

HEALTHGUARD AEROQUIPMENT

HIGH DUTY ALLOYS LTD.

HELLIWELLS LTD.

H. M. HOBSON (AIRCRAFT AND MOTOR) COMPONENTS LTD.

Hobson

THE HESTON AIRCRAFT CO., LTD.

S. HUBBARD LIMITED

MECHOFELT
HUBBARD MECHANICAL FELT

THE HEYWOOD COMPRESSOR CO., LTD.

Hymatic

COMPRESSED AIR EQUIPMENT

F. A. HUGHES & CO., LIMITED

Distributors of
ELEKTRON
REGISTERED TRADE MARK
MAGNESIUM ALLOYS

HIDUMINIUM APPLICATIONS LTD.

HENRY HUGHES & SON LTD.

THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY

With which is incorporated The Institution of Aeronautical Engineers

CONTENTS *JANUARY, 1945*

	Page
FOREWORD By Sir A. H. Roy Fedden, K.B.E., D.Sc., F.R.Ae.S.	1—3
NOTICES	4—7
HISTORY OF THE AERONAUTICAL JOURNAL By Captain J. Laurence Pritchard, Hon. F.R.Ae.S.	8—13
RATIONALISATION OF ALUMINIUM ALLOY SPECIFICATIONS By A. E. Russell, B.Sc., F.R.Ae.S. ..	14—20
THEOREMS FOR THE SYNTHESIS OF SIMPLY-STIFF FRAMEWORKS By H. Roxbee Cox, Ph.D., B.Sc., D.I.C., F.R.Ae.S.	21—25
DESIGN FACTORS OF CIVIL AIRCRAFT AFFECTING THE OPERATING COSTS By R. K. Pierson, C.B.E., B.Sc., A.M.Inst.C.E., F.R.Ae.S.	26—32
REVIEWS	33—34
ABSTRACTS	35—44
LIST OF BRANCHES	vii—ix
LIST OF COUNCIL	xviii
COMMITTEES OF COUNCIL	xix
THE SOCIETY'S PRIZES	xx—xxi
DIRECTORY OF ADVERTISERS	xxx—xxxiv

The Journal of The Royal Aeronautical Society was founded in 1897 in succession to the Annual Reports. For the opinions expressed in Papers that are signed or initialled the authors alone are responsible. None of the papers or paragraphs must be taken as expressing the opinion of the Council of The Royal Aeronautical Society unless such is definitely stated to be the case. **The Journal is published monthly at the Offices of the Society, 4, Hamilton Place, Piccadilly, London, W.1.** Subscriptions per annum, £4 10 0 post free; Single Numbers 7/6 or 7/9 post free. All communications for publication in the Journal, or on general matters affecting the Society should be addressed to—The Secretary, J. Laurence Pritchard, 4, Hamilton Place, W.1. The Society's Bankers are Messrs. Coutts and Co. All communications respecting Advertisement matters should be addressed to—The Advertisement Manager, Journal of The Royal Aeronautical Society, 4, Hamilton Place, W.1.

Telephone: Grosvenor 3515-3516-3517. Telegraphic Address: Didaskolas, Audley, London.

THE ROYAL AERONAUTICAL SOCIETY

With which is incorporated The Institution of Aeronautical Engineers

PRESIDENT:

SIR A. H. ROY FEDDEN, M.B.E., D.Sc., F.R.Ae.S., M.I.Mech.E., M.I.A.E., M.S.A.E.

PAST PRESIDENTS:

A. GOUGE, B.Sc., F.R.Ae.S.

GRIFFITH BREWER, Hon.F.R.Ae.S.

LORD BRABAZON OF TARA, M.C., F.R.Ae.S.

VICE-PRESIDENTS:

W. C. DEVEREUX, F.R.Ae.S.

R. K. PIERSON, C.B.E., B.Sc., F.R.Ae.S., A.M.Inst.C.E.

COUNCIL:

E. J. N. ARCHBOLD, B.Sc., Grad.R.Ae.S.

Air Commodore F. R. BANKS, O.B.E., F.R.Ae.S., M.I.Aut.E., F.I.P., M.S.A.E.

A. C. BROWN, B.Sc., F.R.Ae.S.

S. CAMM, C.B.E., F.R.Ae.S.

W. C. DEVEREUX, F.R.Ae.S.

G. H. DOWTY, F.R.Ae.S.

A. G. ELLIOTT, C.B.E., F.R.Ae.S., M.I.Aut.E., M.S.A.E.

S. H. EVANS, B.S., F.R.Ae.S., A.F.I.Ae.S.

Major F. B. HALFORD, M.S.A.E., F.R.Ae.S.

Major R. H. MAYO, O.B.E., M.A., F.R.Ae.S., A.M.Inst.C.E.

N. S. MUIR, B.Sc., A.F.R.Ae.S.

R. K. PIERSON, C.B.E., B.Sc., F.R.Ae.S., A.M.Inst.C.E.

G. E. PETTY, F.R.Ae.S.

N. E. ROWE, C.B.E., B.Sc., A.C.G.I., D.I.C., F.R.Ae.S.

A. E. RUSSELL, B.Sc., F.R.Ae.S.

Sir FRANCIS SHELMERDINE, O.B.E., C.I.E., F.R.Ae.S.

Major B. W. SHILSON, O.B.E., M.I.Mech.E., F.R.Ae.S.

Sir OLIVER SIMMONDS, M.A., F.R.Ae.S., M.P.

R. S. STAFFORD, A.F.R.Ae.S.

C. C. WALKER, F.R.Ae.S., A.M.Inst.C.E.

Hon. Treasurer : Captain A. G. LAMPLUGH, F.R.Ae.S.

Solicitor : LAWRENCE A. WINGFIELD, M.C., D.F.C., A.R.Ae.S.

Hon. Librarian : J. E. HODGSON, Hon.F.R.Ae.S.

Hon. Accountant : A. N. D. SMITH, F.C.A.

Secretary : Captain J. LAURENCE PRITCHARD, Hon.F.R.Ae.S., Hon.M.I.Ae.S.

FOREWORD

by

Sir A. H. Roy Fedden
K.B.E., D.Sc., F.R.Ae.S., M.I.Mech.E., M.I.A.E., M.S.A.E.

Sir Roy Fedden is known throughout the world as the designer of such famous engines as the Jupiter, Mercury, Pegasus, Perseus, Hercules and others. He has received the highest awards for his work, among them the Manley Award in 1933 in America, the Guggenheim Medal in 1938, the Simms' Gold Medal of the Institution of Automobile Engineers in 1934, and the Silver Medal of the Society. In 1944 he read the 32nd Wilbur Wright Memorial Lecture.

AS I take over the Presidency of our Society for the second time within a few years, my first desire is to express to the Council my deep appreciation of their confidence in paying me this high honour. It is, indeed, a great privilege to be chosen to serve the oldest Aeronautical Society in existence in such a manner, especially at the present time, as we embark upon what I believe will be a fateful—and I hope, fruitful—year in the Society's history. It will be my endeavour to further the interests and welfare of our Society to the utmost, in what we all hope may be the immediate post-war period. We have, I think, a hard time ahead of us, and I shall be grateful for all the help that the Council and members can give me.

In 1939, it will be recalled, the Society had plans far advanced for increased activity; it had been established in its present permanent home at Hamilton Place; it had raised its Endowment Fund to a level more commensurate with its true status and dignity in the rapidly-expanding world of aeronautics; and it had arranged an International Aviation Congress at Stratford-on-Avon.

Then came September 3rd, and with it the postponement of the Society's more ambitious plans. When I entered upon my second year of office in October, 1939, I wrote a letter to our members which was printed in the Journal, and in which I advised them of the changes in our general policy, which the outbreak of war had necessitated. It was with great regret that I had to do this, for at that time we seemed to be on the verge of achieving more nearly our rightful place in the aeronautical world.

Five years have now passed: five years of the most outstanding progress in the science and technology of aeronautics that we have yet known. For security reasons most of the advancement of knowledge which has come about has had to remain secret, and the Society has not been able to play its usual

part in disseminating it. Nevertheless, we have done important work through our various technical committees and representation, and also by holding a number of conferences and debates on a variety of subjects, while, at the same time, keeping such things as the Wilbur Wright Lecture, the Journal and the Library going on the highest possible level under most difficult circumstances. I feel I should take this opportunity of paying tribute to Captain Pritchard and the staff at Hamilton Place for all the hard work they have put in in working out the necessary arrangements.

I would like now to touch on the question of our technical sphere of influence in the post-war years. It is the duty of all of us to work on the Society's behalf so that it may attain the strength and vigour which will ensure it taking first place, as far as aeronautics is concerned, among the great engineering and scientific institutions of the world. We must look forward to the time when no man of accomplishments in aviation will think of being outside our membership, simply because our activities are so necessary to the whole sphere of aeronautics and our status so established that we hold a position which is universally recognised as being supremely important. At the same time we must see to it that we maintain a friendly and collaborative relationship with all other institutions with a professional interest in matters aeronautical. I believe all this can be achieved on a perfectly happy basis, but to accomplish it we must be active and progressive now, and I trust we shall all play our individual parts enthusiastically.

There are at present two Sub-Committees of the Society which have for some time been doing the sort of work I am referring to. They have carried out some excellent work during the war years, but for security reasons it is not permissible to state exactly what that work is. Both these Committees have received considerable recognition in this country and America.

During the last few months the Council has had this problem of increased technical activity very much in mind, and I am glad to be able to tell you that it has now been decided to add to the number of technical Sub-Committees, so as to cover the whole field of aeronautics, and it will be their job to tackle all technical and scientific problems which properly fall within the Society's scope, such as those dealing with aerodynamics, structures, engines, etc.

There are several other ways, too, in which the Society intends to expand its activities, thereby making itself an instrument of greater usefulness to aeronautics in general and also, at the same time, catering more fully for the needs of its members. All this means more work than Captain Pritchard and the present staff can hope to cope with, and arrangements have been made for the staff to be strengthened technically and expanded in other directions also.

It will be seen, therefore, that the Council is alive to its responsibilities towards upholding British prestige in aeronautics and furthering technical progress. I hope they will receive the active support of every member, and, furthermore, if any member feels he can make any useful suggestions for the good of the Society, I hope he will write to the Secretary about it.

Increased activities involve increased expenditure, and if the Society is to achieve maximum effectiveness it must be assured of a greater income and a larger and more virile membership. Already, through the excellent efforts of the Journal Committee, a scheme has been devised whereby more space is devoted in the Journal to technical matter. This is the first copy of the Journal to be produced under this arrangement, which is admittedly a temporary one dictated by wartime paper controls, and we are most grateful to our advertisers, whose co-operation has made it possible.

This alone, however, is not enough, and it should not be taken for granted that this

source of income will progressively increase in the post-war years, when conditions must necessarily be a good deal different from what they are to-day. The surest way of increasing our income is to have a larger permanent membership. It is good to note that during the war there has been a steady increase in the numbers on our books, and we must strive to ensure that this progress is maintained. There are still many men actively connected with aeronautics who have the necessary attainments, but who are still outside our ranks, and this alone suggests that we have not yet made the Society the vital force that it should be, and which is appropriate to its proud claim to be the oldest society in the world devoted entirely to aeronautics.

What else can we do to achieve our goal? One obvious thing is to improve and widen the interest in our branches. Before the war we had 16 branches, covering the principal centres of aviation in the United Kingdom and also in some of the British Dominions. The war, of course, has made meetings difficult, but it is unfortunate that some of these flourishing branches, whose meetings were filled to overflowing before the war, have now ceased to function altogether, although I do not overlook the fact that others are still operating and are doing very well indeed. Others are just starting up again, and I hope there will be members in other districts, not now covered, with sufficient keenness to form new ones. In February, we are also resuming our lecture programme at Headquarters.

In this connection I feel that the Graduates' and Students' Section is worthy of a special word of praise. Throughout the whole of the war they have enthusiastically carried on their programme of lectures, visits and film shows and have done splendid work.

All this, then, provides a medium whereby we can all do our share in furthering the aims of the Society and interesting a wider circle of potential members in its work. During the last year or two, my work for the Minister of Aircraft Production has taken me to a large number of firms in the aircraft and allied industries, and it seems to me significant that in the course of these visits many young engineers have spoken to me about the Society, asking such questions as: Is it worth while joining it? How shall I benefit my future career in aviation by joining? What qualifications are necessary? Is it not somewhat of a dull, academic sort of affair? and so on. There is, I am convinced, a large and valuable group of people who only need guidance and encouragement to bring them into some suitable grade of the Society.

There is one other point on which I would like to touch. I am sure we are agreed that anybody accepting office in our Society is undertaking a really serious job for the advancement of aeronautics and for the good of the country, and that our work therefore is of the first importance. Unfortunately, in the past, this view has not always been taken. I hope, in the immediate future, to see more people prepared to take an active interest in the Society, and to appreciate that, in doing so, they are assuming a considerable responsibility, which it is incumbent upon them to fulfil to the utmost. If we ensure the efficient conduct of our committees and other activities we can bring the whole world of aeronautics to see that our work is just as important and useful as any other branch of aviation.

I should like to close with a note of appreciation of the sterling work of our retiring President, Mr. Arthur Gouge, who has held office during two most difficult years of the war. He has brought a great deal of vision and tact into our problems and he has been responsible for initiating new moves for our post-war activities, while he has done much to promote good feeling and a more progressive outlook throughout the Society. For me to continue his work and to do with the same efficiency will be no easy task.

JANUARY NOTICES 1945

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members will contribute papers on their own special subjects.

Prime Minister

The following telegram was sent to the Prime Minister on his seventieth birthday:

The Council and all members of the Royal Aeronautical Society wish to send you their heartiest congratulations on your seventieth birthday. The Council at their meeting today unanimously resolved to offer you Honorary Fellowship of the Society, the highest membership honour they can give, in recognition of your very great services to aviation.

ROY FEDDEN,
President.

The following letter has been received by the President:

10, Downing Street,
Whitehall.
December 19th, 1944.

Dear Sir Roy Fedden,

The Prime Minister has received with pleasure the invitation which you sent him on behalf of the Council and Members of the Royal Aeronautical Society to become an Honorary Fellow of the Society. Mr. Churchill is glad to accept this honour, which is one that he will greatly prize, and he has instructed me to convey to you and the Members of the Council his warm thanks for this mark of their friendship and goodwill.

Yours truly,
(Signed) JOHN COLVILLE.

Premium Awards

Particular attention has been drawn above to the award of premiums for the most meritorious papers published in the JOURNAL. It is hoped that these awards will encourage members to write for the JOURNAL. The Editor will gladly welcome any suggestions for papers, and it would add considerably to the values of the suggestions if the names of suitable authors could be made at the same time.

Titles and Notices

The Titles and Notices which have been published with the JOURNAL for some time past will no longer be issued. For those who wish to have them, however, they may be obtained from M.A.P. R.T.P.3, and also a list of Translations. Copies of the lists of Translations available are also kept in the Library of the Society.

Increase in Price of Journal

The Council have decided that on and from January 1st, 1945, the price of the JOURNAL should be increased to 7s. 6d. per issue to non-members (£4 10s. per annum).

Lectures 1945

The following programme of lectures has been arranged to be held, with the exception of the discussions on Civil Aviation, at 6.30 p.m. in the Lecture Hall of the Institution of Mechanical Engineers, Storey's Gate, St. James', S.W.1 (by permission of the Council of the Institution). Members do not need

admission tickets, but visitors must obtain a ticket through a member.

Tuesday, 23rd January—Discussion on Civil Aviation, at **5.30 p.m.**

Thursday, 8th February—Discussion on Civil Aviation, at **5.30 p.m.**

Thursday, 15th February—Aircraft Wheels and Brakes by Mr. J. Wright, A.F.R.Ae.S.

Tuesday, 20th February—The Importance of Power Plant Development, by Air Commodore R. Banks, F.R.Ae.S.

Thursday, 1st March—Control Surface Design, Joint Lecture by Mr. M. B. Morgan and Mr. Thomas.

Thursday, 8th March—Electrics for Aircraft, by Mr. C. G. A. Woodford, A.F.R.Ae.S.

Tuesday, 13th March—Discussion on Civil Aviation, at **5.30 p.m.**

Thursday, 22nd March—Hydraulics for Aircraft, by Mr. R. H. Bound, F.R.Ae.S.

Thursday, 5th April—Modern Experimental Work on Aeroplane Structures, by Dr. A. G. Pugsley, F.R.Ae.S.

Thursday, 31st May—33rd Wilbur Wright Memorial Lecture, by Mr. T. P. Wright, Hon.F.R.Ae.S.

Branch Lectures

LUTON BRANCH

Lectures are held at the Technical College, Luton, at 7.15 p.m.

Wednesday, 10th January—Flight Testing of Aircraft Control and Stability, by Dr. D. Cameron.

MEDWAY BRANCH

Lectures are held at 7.15 p.m.

Monday, 8th January—Light Alloy Castings, by Mr. F. Hoult.

Monday, 12th February—Compressibility, by Dr. W. F. Hilton.

Monday, 12th March—Engine Installations, by Mr. F. Mayer.

Monday, 9th April—Work in an Experimental Seaplane Tank, by Mr. L. Smith.

BELFAST BRANCH

Lectures are held in the Central Hall, College of Technology, at 6.30 p.m.

Monday, 8th January—Film Evening.

Monday, 29th January—Production and Works Organisation, by Mr. W. Browning, A.F.R.Ae.S., A.M.I.Mech.E., M.I.P.E.

Monday, 26th February—Production Control, by Mr R. Beaney, A.F.R.Ae.S., A.M.P.E.

Monday, 26th March—Inspection, by Mr. W. H. Bell, A.F.R.Ae.S.

Monday, 16th April—Test Flying, by Mr. J. Lankester Parker, F.R.Ae.S.

BRISTOL BRANCH

Lectures are held in the Conference Room, Bristol Aeroplane Company, Filton House, Bristol, at 6.30 p.m., by kind permission of the Directors.

Tuesday, 16th January—Flight Testing, by Mr. E. T. Jones, A.F.R.Ae.S.

Tuesday, 6th February—Plastics: Their Industrial Application, by Mr. H. Carl Martin.

Tuesday, 20th February—Flying Boats, by Mr. A. Gouge, F.R.Ae.S.

Tuesday, 6th March—Development in Rotating Wing Aircraft, by Mr. R. Hafner.

Tuesday, 20th March—Film Night and Annual General Meeting.

Election of Council

Attention is drawn to the following Rules for election of Council. Nominations should be received by March 3rd, 1945. Nomination forms may be obtained from the Secretary. Attention is drawn to possible delays in the post at the present time. Nomination forms may be signed by any members of the Society excepting Honorary Fellows, Graduates and Students.

Rule 17.—One-half of the Council (excluding the President and the immediate Past-President if a Member of Council) shall retire annually. The members who shall retire shall be those longest in office, except as provided in Rule 77. Retiring Members of Council who have served for two terms in succession (four years) shall not be eligible for re-election until the next annual election, when they will be eligible.

Rule 72.—The composition of the Council shall be as follows:—

(*a*) Not less than sixteen shall be elected from the technical or scientific grades of the R.Ae.S.—that is to say, from among the Fellows, Associate Fellows and Associates.

(*b*) Of these sixteen, four at least shall be Fellows.

Rule 73.—Nominations of candidates for election to the Council must be received by the Secretary not less than twenty-one days before the Annual General Meeting, with an intimation in writing by the candidates that they are willing to serve. Nominations must be signed by one supporter and two seconders, who must be each entitled to vote in the R.Ae.S.

Fellowship

Members are reminded that under the rules election to Fellowship is made annually and that all nominations must be received by March 1st at the latest on Form A obtainable from the Secretary.

British Empire Lecture

The attention of all members residing in the British Dominions and Colonies is drawn to the new British Empire Lecture, entries for which should be received by May 31st, 1945. It is hoped that this lecture will become second only in importance to the Wilbur Wright Memorial Lecture. Further particulars of the lecture will be found on pages xx and xxi.

Annual Subscriptions of Members

Members are reminded that their 1945 subscriptions will become due on 1st January, 1945.

The Council are very grateful to all those members who have offered to forego their JOURNALS for the duration of the war . The same reductions will be made to the 1945 subscriptions of these members as applied to the 1944 subscriptions. Subscriptions of Fellows, Associate Fellows, Graduates, Companions and Founder Members who have given up their JOURNALS will therefore be reduced by 10s. 6d. Associates will receive the reduction already laid down in the Rules, and the low subscription at present paid by Students does not permit any reduction to be made.

The following will be the rates for 1945 therefore:—

	Home receiving Journal. £ s. d.	Home not receiving Journal. £ s. d.	Abroad receiving Journal. £ s. d.	Abroad not receiving Journal. £ s. d.
Founder Members	2 2 0	1 11 6	2 2 0	1 11 6
Fellows	4 4 0	3 13 6	3 3 0	2 12 6
Associate Fellows	3 3 0	2 12 6	2 2 0	1 11 6
Associates	2 2 0	1 1 0	2 2 0	1 1 0
Graduates (age 21-25)	2 2 0	1 11 6	2 2 0	1 11 6
,, (age 26-28)	2 12 6	2 2 0	2 12 6	2 2 0
Students	1 1 0	1 1 0	1 1 0	1 1 0
Companions	2 2 0	1 11 6	2 2 0	1 11 6

NOTICES

Binding of Journals

Owing to increased costs, the prices of binding of all JOURNALS will be as follows:

1944 Volume	9s. 0d.
Previous Volumes	11s. 0d.
Library Catalogue bound separately (from 1941 Vol.)	10s. 0d.

JOURNALS for binding should be sent direct to The Lewes Press Limited, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the office of the Society.

Election of Members

Associate Fellows

Henry Frederick Trelawney Adams, Reginald William Bell (from Graduate), Latham Valentine Stewart Blacker, Frederick James Bradbury, Francis Ernest Bridges, James Collier, John Oliver Doley (from Graduate), Ernest Graham Dunsford, Henry George Ewing (from Graduate), Maurice Fine, Arthur Sherlock Foreman (from Graduate), Donald Andrew Gibson, Sydney Goldstein, Louis Alfred Hall, John Vivian Holman (from Associate), Roland Antoni Kalpas, Raghunath Shamrao Khot (from Graduate), Noel Reginald Fortescue Mortimer (from Graduate), Kazimierz Wladyslaw Nowicki, Idris Lloyd Phillips, Eric Lewis Ripley (from Student), Herbert Sammons, George Thomas Smith-Clarke, Venus Charles Venus, Geoffrey Harold Wass, Edmund Wilson.

Associates

Harold Cyril Adams, Arthur Kenneth Baker (from Student), Douglas Frederick Bate, John Kinrade Beaumont, Norman Ralph Alexander Biles, John Gordon Brandon, Harald Martinsen Buberg, Eric Joseph Cheshire, Frederick David Cheshire, Cyril William Chick, Maurice Hughes Cook, Henry Walter Cooke, Alexander Douglas Duncan, Edward Eltenton, Albert Harry Ford, Andrew Paul Guinand, Terence Michael Hainsselin, Kenneth Lloyd Harris, Cyril Philip Homes, John Tetley Horsfall, George Halstead Kalwig, Richard Los, Francis Logan Luxmoore, Robert John McAusland, George Thomas Kenneth McHugh, Ian Ludwig Steel McNicol, Geoffrey Douglas Mann, W. A. Canning Murtagh, Nelson Digby Neave, Shamais Ian Ruerie McIver, Eric Newton, George Alfred Stanley Palmer, Donald Frosdycke Smith, Edward A. Smith, Francis Tipler, John Leversage Walker, Charles Herbert Winterbourne, Jack Woodhouse.

Graduates

Derek Roy Bettison, Simon Brenner (from Student), Ian Buchan, Francis Jeffrey Colville, Derek Grove Croudson (from Student), Peter Henry Curnow, Peter Rivers Doudney (from Student), William Downes, Cedric Stanley Clayden Miller, Harold Edgar Parish, Arthur George Rodd, Moiz A. Sevik, Michael Kenneth Sivers, Douglas Oliver Spratt, Richard Herbert Taylor, Geoffrey Buckley Wootton.

Students

Camille Armand Frederic Arthur Aylward, Peter Byron, Alric Ronald Cawthorne, Geoffrey Samuel Canetti, Douglas Thomson Clark, Thomas Arthur Coombs, Kenneth Howard Dickenson, Standley Thomas Alan Featherstone, Ulric Keith Gerry, Michael Barker Glauert, John Grieve, Leslie John Hakes, Joseph Percy Harley, Adrianus Henderikus Davidus Hoppener, Keith Spencer Jeffery, Geoffrey George Jenkinson, Keith Leonard Charles Legg, Alastair Munro Mackie, Ralph Mackinder, Peter Alec Marks, Benjamin O'Reilly, Lewis Raymond Phillips, John Reighcraft Purchase, Raymond Henry Siddons, Douglas Stewart Southwell, Colin William Starling, Terence Courtney Taylor, Robert Smyth, Geoffrey Michael Trewinnard, John Francis Thring, Ronald Horace Warring, Donald Charles Woodcock.

Companion

John Crowther.

J. LAURENCE PRITCHARD,
Secretary

HISTORY OF THE AERONAUTICAL JOURNAL

by

Capt. J. Laurence Pritchard
Hon. Fellow

Captain J. Laurence Pritchard has been the editor of the Journal for the past twenty-five years, and Secretary of the Society for twenty years. He took an Honours degree in Mathematics at Cambridge, served in the Royal Naval Air Service in the war of 1914-18, and has written the Book of the Aeroplane, Aeroplane Structures (with A. J. S. Pippard), Broadcast Reception in Theory and Practice, and numerous other books. His first article on the aeroplane appeared in February, 1910.

THE Journal of the Royal Aeronautical Society, in one form or another, is the oldest aeronautical publication in the World, with a continuous record of publication.

The Aeronautical Society of Great Britain was founded on January 12th, 1866, and the first report of the proceedings of the Society was published in 1867 by the firm of Cassell, Petter and Galpin, of Ludgate Hill, E.C., price 1s. 6d.

It was a bold venture to start an aeronautical society in those days, and it is worth while recalling the year 1866. It was the year Prussia became head of the new German confederation which was the beginning of modern Germany, and it was the year that the first treaty of alliance was signed between Italy and Germany.

In those days Dickens, Browning, Tennyson were the giants of their time. Women wore crinolines, shawls and poke bonnets, and men light trousers with frock coats and top hats. England was stirring uneasily with the consciousness of the coming power of science. Those were the days of enterprise for the bold, of new industries being founded, new visions ahead, fitting days for the birth of the aeronautical infant which was to grow into a giant with wings to carry him across the seven seas, to decide the destinies of nations, to change the face of the World.

The second meeting of the Council of the Society was held on February 12th, 1866, with the Duke of Sutherland in the Chair. At this meeting a letter was read from the Society's first President, the Duke of Argyll, expressing a wish that when the Council was in a position to do so a Journal should be published in the interest of the Society.

Eleven meetings of Council were held in 1866, and though ballooning was the only practical form of rising in the air, the Council from the first turned its attention to the possibilities of heavier-than-air machines. At the Council meeting, held on May 23rd, 1866, the Duke of Sutherland offered a prize

of £100 for anyone who could by mechanical means fly from the garden or from Green Park to the top of Stafford House.

At the meeting of August 24th, 1866, there was passed the following remarkable and significant resolution.

" It was delegated to the Duke of Argyll, Lord Dufferin, Mr. James Nasmyth, Mr. J. McConnell, Mr. Glaisher and Mr. Wenham, to consider the law of resistance of inclined surfaces moving in elastic and non-elastic fluids, as air and water, and the resultant force obtained at right angles to the direction of motion. Experiment has now proved that as the velocity is increased, and the angle of inclination diminished, the centre of effort of the plane approaches forward, till nearly the whole effect of reaction or support is transferred to the front edge. It therefore follows that in very acute angles with the line of motion, a given extent of reacting surface at high velocities will be most effective if disposed in a narrow plane extended transversely to its direction."

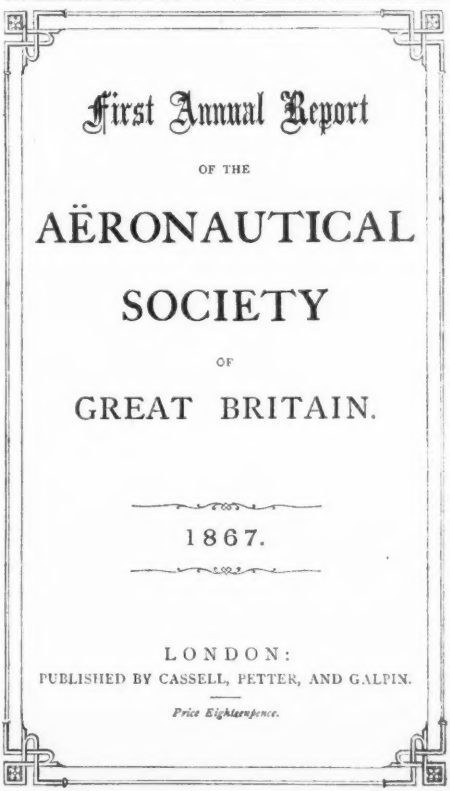
It was the first real effort to face up to the problem of finding the force on a given surface at a given speed at varying angles of attack. August 24th, 1866, is one of those dates in aviation which should be remembered, and remembered ever to the credit of the Council of the Aeronautical Society of Great Britain. It was the day when the Society began to tread firmly the road which was ultimately to lead it to become the leading aeronautical body in the World devoted to the advancement of aeronautical engineering and science.

At the January 1867 meeting of the Council, the first Annual Report for 1866 was passed and ordered to be printed. At that time the total membership of the Society was 65 of whom 24 were honorary, non-paying members. The annual subscription was £1 1s. 0d.

All papers and articles for the Annual Reports, in those early days, were read by the Council and passed for publication, and on occasions there were strong protests to the Council that certain articles on bird flight were not worth publishing.

But the aim of the Council was to provide a history and information on all aspects of flight, and the Annual Reports and the Journal provide an astonishing store of aeronautical knowledge and struggles from 1866 onwards, especially in Great Britain.

In the first Annual Report was published the first public lecture delivered by a member of the Society. This lecture was on June 27th, 1866, and it is significant that it was read on heavier-than-air craft at a time when there was no apparent hope of a mechanically driven heavier-than-air craft becoming a possibility in the lifetime of those present. The author was a qualified engineer, Mr. Wenham, a member of Council, and his


First Annual Report

OF THE

AËRONAUTICAL

SOCIETY

OF

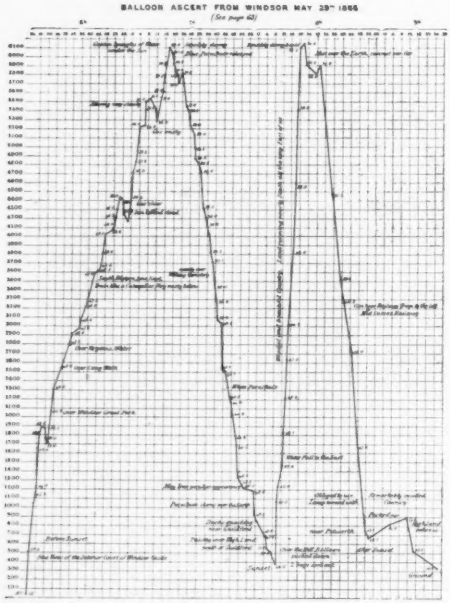
GREAT BRITAIN.

1867.

LONDON:

PUBLISHED BY CASSELL, PETTER, AND GALPIN.

Price Eightpence.



Frontispiece of First Annual Report giving particulars of Glaisher's balloon ascent, May 29th, 1866.

paper was destined to become an aeronautical classic. Wenham, as an engineer, laid down the engineering principles of flight, and discussed, in the light of the knowledge of air resistance of his day, the horsepower required to keep a given weight in the air at a given speed, with a given lifting surface. He drew attention to the importance of aspect ratio, a rigid leading edge, and to the fact that the most important effects of lift were in the first eighth to tenth part of the wing. The greatness of Wenham's lecture lies in the fact that he realised that just those principles which applied to any other form of engineering must apply to aeronautical engineering, and progress could only be made on sound engineering lines.

Wenham took part in many discussions, which are reported in the Annual reports, and his remarks were always very much from the engineering point of view. Time and time again he drew attention to the importance of carrying out proper research on lift and drag.

In the second Annual Report there was an account of a meeting of the Society held on July 15th, 1867, in the Society of Arts, the home for so many years of the Society's lectures. Mr. Butler, in the course of the discussion, stated that he and his brother directors of the Lenoir Gas Engine Company had been experimenting with vapour of petroleum as it was much less in bulk and weight than coal gas.

Even more remarkable, at the same meeting, was the discussion which ensued on the possibility of jet propulsion for driving an aeroplane. Mr. Wenham came to the conclusion " in spite of the costly experiments that have been made to revive the system of jet propulsion, it was clear to him that the screw propeller must be the superior."

First Annual Report

OF THE

AËRONAUTICAL SOCIETY OF GREAT BRITAIN,

FOR THE YEAR 1866;

Containing an Account of the Proceedings, and a Selection from the Papers and Communications received by the Society during the Year, with Concluding Remarks upon the Present State of the Science, &c.

The Preliminary Meeting of the Council of this Society was held at the residence of His Grace the Duke of Argyll, on the 12th day of January, 1866. The following Address was read by Mr. Glaisher :—

" The first application of the balloon as a means of ascending into the upper regions of the atmosphere, has been almost within the recollection of men now living; but, with the exception of some of the early experimenters, it has scarcely occupied the attention of scientific men, nor has the subject of Aëronautics been properly recognised as a distinct branch of science. The main reason of this may have been that, from the very commencement, balloons have been, with but very few exceptions, employed merely for exhibition or for the purpose of public entertainment, and, the first wonder having ceased, sundry performances have been resorted to in order to pander to the public taste for the grotesque and the hazardous, which have tended so far to degrade the subject

Page 1 of First Annual Report, reporting the first meeting of Council, January 12th, 1866

Wenham was referring to jet propulsion, in his final comment, of steam ships and he was correct in his conclusions from the results which had then been obtained.

Many of the earlier papers in the Annual Reports were, as one would expect, on bird flight, and many theories were put forward to account for the flight of birds, but nothing practical came out of them.

The third Annual Report of the Society contained an account of the first aeronautical exhibition ever held in this country, on June 25th, 1868, and the ten following days, at the Crystal Palace.

No fewer than seventy-seven exhibits were collected together, including engines, lighter and heavier-than-air models, kites and plans of projected machines. A prize of £100 was offered by the Society for the engine with the lowest weight/horsepower ratio. The prize was won by John Stringfellow with a steam engine which weighed 13 lbs. and developed one horsepower.

W. H. Phillips, who should not be confused with H. F. Phillips of "Phillips' entry" fame, showed a power-driven model helicopter. He claimed as early as 1842 to have flown one weighing two pounds.

But the outstanding model, as the outstanding engine, was the work of Stringfellow. His triplane model, driven by twin screws and powered by a small steam engine, was supported from a wire, the authority forbidding free flight within the building. I quote from the Annual Report.

"It was seen by several that after a certain velocity had been attained, the machine left the support of the wire and rose up. On one occasion the wire broke just after the start, but the buoyant power of the plane caused so light a descent that no damage occurred."

In this Annual Report there appeared accounts of three meetings and discussions held before the Society. A Mr. Heath put forward the balloon as the flying machine of the future. Mr. Thomas May, a strenuous

The following paper,

On Aërial Locomotion and the Laws by which Heavy Bodies impelled through Air are Sustained, was read by F. H. Wenham, Esq.

The resistance against a surface of a defined area, passing rapidly through yielding media, may be divided into two opposing forces. One arising from the cohesion of the separated particles; and the other from their weight and inertia, which, according to well-known laws, will require a constant power to set them in motion.

In plastic substances, the first condition, that of cohesion, will give rise to the greatest resistance. In water this has very little retarding effect, but in air, from its extreme fluidity, the cohesive force becomes inappreciable, and all resistances are caused by its weight alone; therefore, a weight, suspended from a plane surface, descending perpendicularly in air, is limited in its rate of fall by the weight of air that can be set in motion in a given time.

If a weight of 150 lbs. is suspended from a surface of the same number of square feet, the uniform descent will be 1,300 feet per minute, and the force given out and expended on the air, at this rate of fall, will be nearly six horse-power; and, conversely, this same speed and power must be communicated to the surface to keep the weight sustained at a fixed altitude. As the surface is increased, so does the rate of descent and its accompanying power, expended in a given time, decrease. It might, therefore, be inferred that, with a sufficient extent of surface reproduced, or worked up to a higher altitude, a man might by his exertions raise himself for a time, while the surface descends at a less speed.

A man, in raising his own body, can perform 4,250 units of work—that is, this number of pounds raised one foot

The first page of Wenham's classic paper on Aerial Locomotion read before the Society on June 27th, 1866.

advocate of the heavier-than-air machine, in the course of the discussion remarked: "He would advise them to think of nothing less than 150 miles an hour, as speed would gain the day, and nothing less than that speed." Mr. E. W. Young, an engineer, in the same discussion, drew attention to the curved section of birds' wings and said, "these are not planes; indeed a little consideration would show that the curved surface is better than a true plane."

One can only pick out the high lights from the Annual Reports and the Journal, in such a short review. Whatever criticisms may be made at any given time of the Society's activities, the publications of the Society's work show only too clearly how alive

members were to aeronautical problems of all kinds.

In the Annual Report for 1869 was published a paper by Mr. D. S. Brown in which he drew attention to the use of aluminium for the construction of light engines. It was the first mention of the possible use of aluminium in aircraft, some fifty years before its use became of real importance.

In those days, there was more freedom in the debates before the Society and in the reports, than now. A Mr. Sherward read a paper on an aeroplane he had designed. The Chairman, winding up the discussion, commented: " I suggest that a trial with a few sheets of paper would convince Mr. Sherward of the impracticability of his scheme," and Mr. Wenham added: " If the writer of the paper had more experience, he would not stumble over the first elementary steps."

In the 1870 Report is an account of the first experiments to be carried out in a primitive form of wind tunnel designed by F. H. Wenham, experiments fully reported in the next Annual Reports for 1871 and 1872. In the Report for the following year May gave a description of his " aerial steamer." He was fifty years in advance of his time in one part of his design, in that he fitted his machine with a tricycle undercarriage!

At the present day the effects of travelling near the speed of sound are occupying the energies of aeronautical research workers. In the Annual Report for 1881 in a paper by Scoffern, the author drew attention to the rapid increase in the rate of resistance, " e.g., at a speed exceeding 1,200 ft. per second," to quote his own words, that is near the speed of sound.

Reference has been made to an early brief discussion on jet propulsion. On December 11th, 1886, just over 58 years ago, and printed in full in the 21st Annual Report, was read a paper by Captain Griffiths before the Society, with the prophetic title " Jet propulsion for aeronautical purposes." The paper not only discussed jet propulsion, but drew attention to rocket propulsion as well!

" My plan," said the author, " is to use something similar to the gas engine, but substituting for the piston a nozzle, and, if possible, using, instead of explosions, a continuous stream like a rocket, . . . Now for a motor. There is nothing can be compared to the jet system for simplicity and smallness of volume."

The author proposed to use hydrogen mixed with air and finished his lecture with the remark: " If we have to look for a lighter motor than this, I believe our case is hopeless."

In the 1891 Report Maxim gave a preliminary account of his own experiments which were the boldest of his day, and in 1893 was published an account of the curved wings of Horatio Phillips, a member of the Society, and their remarkable lifting power.

In January 1897 the following letter was sent out by the Honorary Secretary, Captain B. Baden Powell, who afterwards became President of the Society. Three hundred copies of the new Journal a quarter were printed and the price was 2/- per copy.

Sir,—

I am desired by the Council of the above to inform you that, in view of the increasing interest now being taken in the subject of Aerial Navigation, it has been decided to endeavour to place this Society on a more useful footing. The Council propose, should sufficient support be given, to greatly increase the scope of the Society, to issue a Journal at least quarterly, containing not only reports of meetings of the Society, but original articles, reprints, and records of all that is going on at home and abroad in the subject of Aeronautics, and all news likely to be of interest to members, to hold frequent meetings for the reading and discussion of papers and exhibition of models; to collect a library of books and periodicals for reference of members; and, if possible, to procure the use of a room as a library and museum.

It is hoped that all interested in the subject will do what they can towards the object in view, by becoming members or inducing others to join, by contributing books, etc., to the library, and by submitting papers and articles on the subject for reading at the meetings, or for publication in the Journal.

The subscription will be, as heretofore, one guinea per annum.

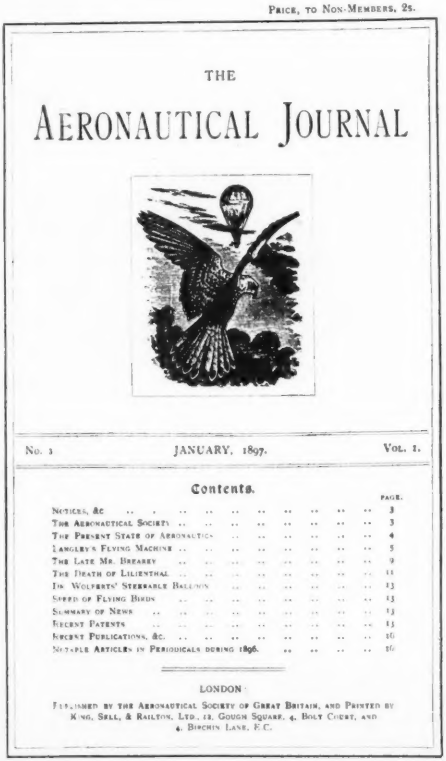
The first quarterly issue consisted of 16 pages of reading matter. The quarterly was published regularly until 1917 when the Council decided, as from January 1918, the Journal should be published monthly. During the twenty years of its existence as a quarterly, there were published in the Journal, one may recall, Wilbur Wright's article on angle of incidence (1901); a description of the experiments of the Brothers Wright (1906); papers by Handley Page on pressures on plane and curved surfaces moving through the air (1911); Eiffel's recent research work (1912), the comparison of monoplanes and biplanes (1913) and other papers by him; papers on airscrews by many members, particularly Turnbull, Baden-Powell, Parsons, Herbert Chitty and G. H. Bryan. In these pages between 1897 to 1917 appear well-known names, beside those mentioned, as authors of papers, Wenham, B. Melvill Jones, Lord Rayleigh, Octave Chanute, Mervyn O'Gorman, Jose Weiss, B. C. Hucks, F. W. Lanchester, Professor Langley, S. F. Cody, A. V. Roe, Lilienthal, Pilcher, Lawrence Hargrave, Professor Bairstow and many others.

Since its publication from 1918 to the present time, as a monthly the Journal has been chiefly devoted to complete reports of lectures read before the Society, for the publication of special papers, records of the Society's activities and the like.

The Society is now entering on a new era of activity and the Journal will reflect in its papers the aeronautical age which is now beginning. Its publication during the last seventy-eight years in one form and another has provided a unique record of aeronautical history and progress, particularly in this country. Its publication during the next seventy-eight years will, I am sure, give a record which will be one of continuous and remarkable progress by members of this, the oldest aeronautical Society in the world.

I should like to end this all too brief survey with a quotation from the Annual Report of 1893.

"This little Society, which at no time numbered more than one hundred members, and which for some years has barely numbered thirty, may be congratulated upon the influence which it has exercised in all parts of the world where the subject is studied, and where during twenty-eight years its reports have been circulated."



PRICE, TO NON-MEMBERS, 2s.

THE

AERONAUTICAL JOURNAL

No. 1 JANUARY, 1897. VOL. I.

Contents.

	PAGE.
NOTICES, &c.	1
THE AERONAUTICAL SOCIETY	3
THE PRESENT STATE OF AERONAUTICS	4
LANGLEY'S FLYING MACHINE	5
THE LATE MR. BREAREY	9
THE DEATH OF LILIENTHAL	11
DR. WOLFERTS' STEERABLE BALLOON	13
SPEED OF FLYING BIRDS	13
SUMMARY OF NEWS	13
RECENT PATENTS	14
RECENT PUBLICATIONS, &c.	16
NOTABLE ARTICLES IN PERIODICALS DURING 1896.	16

LONDON:

PUBLISHED BY THE AERONAUTICAL SOCIETY OF GREAT BRITAIN, AND PRINTED BY KING, SELL, & RAILTON, LTD., 12, GOUGH SQUARE, 4, BOLT COURT, AND 4, BIRCHIN LANE, E.C.

RATIONALISATION OF ALUMINIUM ALLOY SPECIFICATIONS

by

A. E. Russell, B.Sc., F.R.Ae.S.

A. E. Russell is the chief designer of the Bristol Aeroplane Company, which he joined in 1926, two years after taking his degree at Bristol University. Promoted chief technician in 1931 and technical designer in 1938, Mr. Russell was last year appointed chief designer. He was elected an Associate Fellow of the Society in 1930 and Fellow in 1939.

ALL aircraft engineers profess a belief in the importance of low structure weight. To implement this belief our efforts must be comprehensive and consistent and in the search for sound method it is important that we review, from time to time, familiar habits that are based on compromise. In the past the comparative merit of a particular aircraft structure has depended on a series of individual assessments, many of them semi-arbitrary. These assessments have covered the whole field from the choice of the initial design load factors and the valuation of the working stresses right up to the ultimate maximum permitted all-up weight.

It cannot be denied that many of the pre-war valuations were haphazard, usually conservative. This is demonstrated by the successful types of aircraft operating in service at weights considerably in excess of their original design estimate. Although this state of affairs proved highly fortunate it is a method that should not be perpetuated. Design must be to a purpose with such margins as may be deemed necessary, catered for logically.

Rationalisation has already been carried a long way. Before studying certain fields where much improvement is still possible a brief survey of the progress already made will put the facts in their proper perspective.

It is first necessary to be able to specify the probable magnitude, variation and frequency of the loads applied to an aeroplane both in flight and on the ground. Knowledge of these values has been increased enormously by the use of V-g recorders and electrical strain gauges. The V-g recorder is an instrument that measures and records accelerations and appropriate speeds on a time-history basis. By putting these instruments to sufficient numbers of aircraft operating under service conditions it is possible to derive the essential basic data wherefrom a logical pattern of strength requirements can be drawn up.

Thus the science of statistics can replace "rule of thumbs." Furthermore cases where it is desirable to balance a gain in operational efficiency resulting from a saving of structure weight, at the expense of strength, it is possible to do so with a realisation of the probable frequency of structural failures.

The effort put into the design of structures to withstand the loads resulting from the many and varied conditions of acceleration is fabulous. This is necessary because it is not sufficient to ensure that failures do not occur. In military aircraft unnecessary weight even in apparently small quantities

Paper received September, 1944.

detracts from operational effectiveness. A simple analysis will demonstrate this. Assume that a bomber is operating at its maximum permitted weight (in practice this actual weight is pushed to a limit determined by experience and tempered by necessity). Typical values for the structure weight and the bomb load may be 30 per cent. and 15 per cent. of the all-up weight respectively. Thus if the structure could be reduced to 29 per cent. (apparently a small saving), 8 per cent. fewer bombers could drop the same weight of bombs. There is no need to expand on the value of such a saving and the effort it would represent spread from the production of raw materials to skilled crews.

Similar arguments apply to civil aircraft. In a recent paper, Dr. Klein, design consultant to the Douglas Co., stated that the value of a saving of 1 per cent. of the all-up weight of a DC-3 was comparable to the total initial cost of the aeroplane.

For these reasons the designers of structures are forced back to fundamentals in their analyses. Men of the highest mathematical ability form a pivotal position in a successful design team as well as in the research laboratories. The magnitude of modern effort is reflected in the growing numerical strength of the design staffs of firms throughout the world and also by the various national efforts to increase their research programmes.

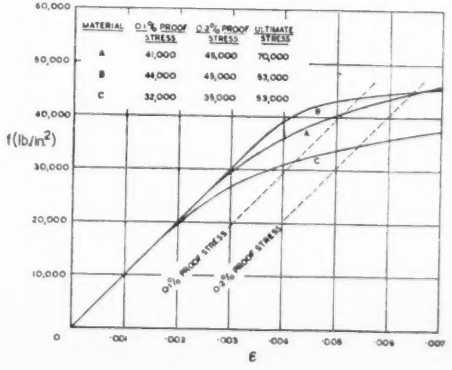
The immediate visible sign of design work is an expensive set of drawings. Among other things these drawings show the dimensions and quote the specification of the materials needed to produce an aeroplane. Whatever the drawings indicate, the practical result depends on the actual physical properties and dimensions of the materials built into the structure. It is important to realise that an aeroplane has not got a precise strength value but a statistical one. That is to say a batch of aeroplanes have a "mean" strength and the variation to be expected can be expressed by a "standard deviation." Those falling at the lower end of the scale receive most prominence and form the basis of approval for the group.

This variation of strength arises, of course, from an inevitable inconsistency in the strength of materials and also from dimensional tolerances inseparable from manufacturing processes. As it is the usual "weakest link" that causes trouble, if it were possible to raise the level of the least strength that passes the acceptance test and/or reduce the dimensional limits that will pass inspection, it would be possible to reduce the built-in surplus and so reduce structure weight.

So far I have attempted to outline in the briefest possible manner the care taken to build up a fundamentally sound technique for determining the minimum strength requirements consistent with safety, the importance of avoiding unnecessary weight and the efforts made by designers to meet these needs. Although I have selected only a few features from the picture it must be appreciated that the complete aeroplane is a mosaic built up from a very large number of small parts. Our objectives can only be reached by control over details and a close watch on the materials from which these details are made.

The weight analysis of a typical twin-engined aeroplane shows that the total structure is made up as follows:—40 per cent. aluminium alloy sheet, 12 per cent.

FIG. 1



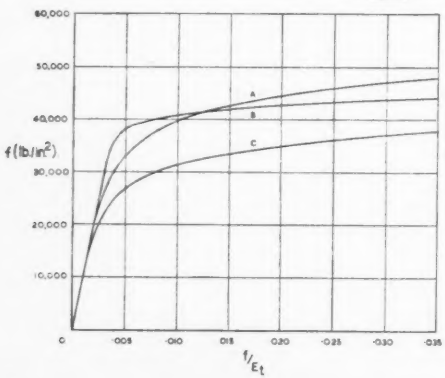
aluminium alloy extrusions, 20 per cent. steel and 28 per cent. miscellaneous (the items under miscellaneous include wheels, axles, shock absorbers, etc.). As would be expected aluminium alloys contribute to more than half the weight of the structure and therefore it is important to examine the control over the specification of these materials.

The main function of a material specification is to serve as a check to make sure that the material employed conforms to the requirements embodied in design. It is the duty of both aircraft designer and material producer to see that the best possible use is made of available alloys in whatever form they may be. So that the one knows what he is using and the other what he is supplying, the agreed values for the physical properties must be quoted in a specification.

Use can be made of certain established principles to indicate the proper values to be quoted.

The major difficulties in designing an efficient structure are encountered in parts in compression. Whether the part is in the form of a strut or a plate, failure occurs by instability. For all such problems, leaving out the geometry of the part, the stress (f) at failure is proportional to the tangent modulus (the tangent modulus E_T is the slope of the stress-strain curve): Therefore the optimum geometrical form of a part in compression is determined by the ratio of the stress to the tangent modulus (f/E_T). Fig. 1 shows certain typical stress-strain curves for aluminium alloys and Fig. 2 shows the appropriate values of f/E_T plotted against f.

FIG. 2



These three curves have been selected because two (A and B) have equal 0.2 per cent. proof stresses and two (B and C) have equal ultimate stresses. Two sample examples will illustrate the use of these curves.

(1) To find the failing stress of a strut having an l/k ratio of 45.

Since

$$f = \pi^2 E_T / (l/k)^2$$

$$f/E_T = \pi^2/45^2 = 0.005.$$

From the curves

For material

A, $f = 33{,}000$ lb./in.^{2}

B, $f = 38{,}500$ lb./in.^{2}

C, $f = 27{,}000$ lb./in.^{2}

(2) To find the buckling stress of a flat plate with all edges fixed, when the width is 2.0in. and the thickness 0.056in.

We have

$$f_b = K E_T (t/b)^2.$$

The value of the buckling coefficient K appropriate to the condition of all edges fixed is 6.3

$$\therefore f_b/E_T = 6.3\ (0.056/2.0)^2 = 0.005$$

giving the same values for stress as example (1).

These results show that, for the examples given, material B having a 0.2 per cent. proof stress equal to material A and an ultimate stress considerably inferior, gives a working stress 16 per cent. higher. An examination of the curves shows that a similar result holds to greater or less degree for all values of f/E_T between 0.0025 and 0.0125.

Certain conclusions can be drawn from these results.

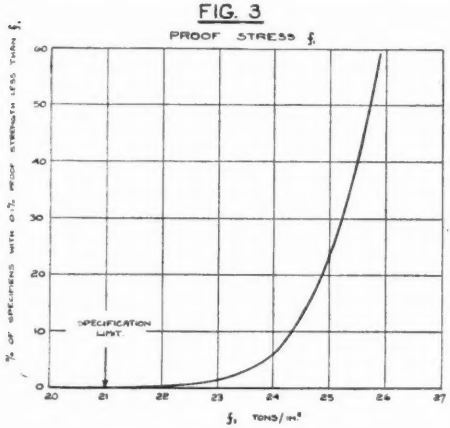
A curve showing f plotted against f/E_T gives the essential strength properties of a material required by a designer of structures.

Without this information it is not possible to compare the merits of one material against another nor to make the best possible estimate of the behaviour of a member in compression. If some appropriate standard curve was established for each aluminium alloy used in primary structures, the usual stress-strain tests could still be the yardstick for inspection.

Returning to the two examples, the results suggest that the present practice of using the 0.2 per cent. proof stress as a measure of merit is quite wrong. The 0.1 per cent. proof stress is a much more accurate indication.

Incidentally, further conclusions can be drawn from these examples. As the value of the tangent modulus varies appreciably with

FIG. 3



relatively small changes in the shape of the stress strain curve, such small changes can produce an appreciable scatter in structural strength from one specimen to another. Also any material which has a low limit of proportionality and proof stress by comparison with the value of its ultimate stress, is inherently unsuited to aircraft primary structures.

When it comes to determining what specification value shall be fixed for a particular alloy a technical difficulty exists. A test value only strictly applies to the particular form of specimen under test. In practice this amounts to a tension test on a round bar or flat strip. Whether or not the expression proof and ultimate stresses are equal to or less than the equivalent tension stresses is a matter of conjecture. A certain amount of mixed evidence exists, but much more information is needed. This defect, however, does not invalidate strong criticism on existing methods.

Fig. 3 shows the results of many thousands of consecutive results on specimens cut from extrusions produced to Specification L.40. It can be seen that all the specimens exceed the specification requirements.

Consider what would have been the result had the minimum requirement been 23 tons/sq. in. instead of 21 tons/sq. in. Firstly, approximately $1\frac{1}{4}$ per cent. of the total number of extrusions produced would have been rejected. Secondly, the designer might have designed his sections to a 10 per cent. higher stress and therefore of approximately 10 per cent. lower weight. As the extrusions in the typical aeroplane amount to 12 per cent. of the structure weight just over 1 per cent. of the structure weight would have been saved. Another effect is also apparent. The aircraft constructor would order 10 per cent. less weight of material. Thus 10 per cent. less raw material would have to be produced at the cost of $1\frac{1}{4}$ per cent. scrap. Obviously it is wrong to adopt a no scrap policy, there must be some economic balance where the weight saved in the structure offsets the cost of the scrap.

Unless some rational method is determined for fixing values, the standard B.S.I. specifications will defeat their own object. The aircraft designer will be driven to make mutual agreements with particular aluminium alloy producers. Instead of design values being forced down by elementary inspection methods, the testing technique must be adjusted so as to permit as high a stress valuation as possible.

The methods of " quality control " appear to be very suitable. Instead of specifications

DETROIT PUBLIC LIBRARY

stating minimum acceptable values, statistics should be collected so that mean values of the limit of proportionality, 0.1 per cent. proof stress, 0.2 per cent. proof stress and ultimate stress together with the " standard deviations " could be quoted. This would permit the designer to choose his working stresses according to the type and duty of the aeroplane under consideration.

Turning now to the present accepted tolerances on the thickness of aluminium alloy sheet. The following is an extract taken from the complete schedule as quoted in:—

TABLE I.

Nominal thickness in.	S.W.G.	24in. wide in.
0.028	22	−0.002 + 0.003
0.048	18	−0.002 + 0.004

Tolerance on thickness 24in. in.	36in. in.	36in. wide in.
−0.002 + 0.003		−0.002 + 0.005
−0.002 + 0.005		−0.003 + 0.006

These requirements are sufficiently flexible for individual interpretation. It is the practice to take the bottom limit as applying to local spots and it is quite simple and safe to take micrometer readings round the edges of a sheet. On the other hand, it is not possible to measure local thicknesses away from the edges without mutilating the sheet. Therefore it is not clear whether the top limit applies to local areas or if it can be taken as an average value which can be

TABLE 2.

MEASURED THICKNESSES OF 16 S.W.G. ALCLAD SHEET 10 ft. × 6 ft.

FIGURES GIVEN ARE IN UNITS OF 0.0001 in. ABOVE NOMINAL (0.064 in.)

DISTANCE ALONG SHEET.	DISTANCE ACROSS SHEET.																									Average.
	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	
0	14	15	15	16	23	27	33	35	35	37	35	35	35	36	38	34	33	28	22	17	13	12	09	08	09	25
6	20	25	26	27	29	31	34	34	37	40	41	41	42	41	42	39	36	34	32	30	25	21	21	17	15	31
12	28	30	33	33	36	40	41	43	46	47	48	48	49	48	49	46	47	47	41	39	37	35	31	28	25	40
18	22	28	30	30	31	36	38	40	41	41	43	45	43	51	42	40	40	43	36	38	35	35	30	25	30	37
24	30	35	40	41	40	43	44	47	48	49	50	49	50	49	49	49	48	46	44	42	43	38	37	33	31	43
30	30	33	37	39	40	41	45	47	49	49	51	52	52	50	50	50	50	48	46	43	42	41	41	47	35	44
36	28	31	32	32	31	33	38	38	40	45	47	48	48	50	48	47	43	41	42	40	32	33	33	28	18	38
42	39	41	44	45	47	49	52	54	54	55	56	56	57	56	56	55	54	51	50	47	49	44	43	41	36	49
48	32	40	40	42	43	45	49	51	53	55	56	58	56	55	55	54	53	53	48	47	45	43	43	43	38	48
54	35	36	37	38	40	40	45	48	50	51	52	52	52	51	50	50	49	50	46	43	42	39	39	35	34	42
60	34	39	40	38	42	45	45	48	51	53	55	55	56	56	54	53	52	51	48	46	44	42	40	38	38	47
66	38	41	42	42	46	49	54	55	58	58	59	60	60	59	58	57	58	55	52	50	48	43	42	41	40	51
72	30	42	45	42	45	49	51	54	55	58	60	60	59	59	58	58	57	55	51	50	48	47	44	40	37	50
78	41	41	43	48	46	48	50	54	56	58	58	65	59	58	58	57	57	53	53	50	50	50	47	44	42	52
84	30	30	31	37	40	42	44	46	50	53	56	52	50	50	51	53	49	48	45	40	41	41	38	34	33	43
90	37	38	39	42	43	40	49	51	52	56	57	58	57	57	56	55	54	52	52	49	45	43	46	42	41	49
96	42	42	43	48	50	51	52	53	56	60	60	60	60	57	57	56	54	52	50	47	45	41	40	39	40	50
102	26	30	31	32	38	38	46	44	45	47	48	48	49	51	48	53	53	40	41	41	39	37	36	35	42	41
108	34	35	38	41	44	46	46	52	52	52	54	54	54	53	52	51	49	48	45	43	43	40	39	39	39	46
114	37	28	30	34	37	43	46	50	62	52	54	54	54	53	52	51	49	48	48	43	43	40	39	39	39	43
120	11	8	8	8	10	15	27	32	32	35	39	38	31	32	37	38	37	35	32	28	24	18	17	29	28	27
Average.	30	33	35	39	38	41	44	46	48	50	51	52	51	51	51	50	49	47	44	42	40	37	36	34	33	

TABLE 3.

MEASURED THICKNESSES OF 14 S.W.G. ALCLAD SHEET 10 ft. × 6 ft.
FIGURES GIVEN ARE IN UNITS OF 0.0001 in. ABOVE NOMINAL (0.080 in.)

DISTANCE ALONG SHEET.	DISTANCE ACROSS SHEET.																									Average.
	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	
0	53	35	41	46	42	56	72	72	70	64	61	65	65	64	69	65	61	60	62	56	48	42	40	38	35	55
6	48	39	40	43	47	54	56	60	63	68	70	71	72	73	70	70	68	67	63	59	53	47	45	43	42	57
12	42	44	47	50	55	59	61	65	67	70	70	72	72	71	71	70	70	66	64	59	58	54	47	47	51	60
18	49	51	52	55	58	66	69	71	73	76	77	77	80	79	78	79	76	72	70	65	63	60	59	53	47	66
24	50	54	56	62	63	68	72	73	75	77	79	79	79	79	78	79	76	74	73	70	62	60	55	54	50	68
30	46	49	53	56	58	64	69	71	74	76	76	78	79	79	80	78	75	74	70	67	62	57	54	51	45	66
36	50	52	60	58	59	63	71	70	72	76	74	80	78	78	80	78	72	72	67	63	60	61	53	48	45	66
42	48	52	54	53	55	61	68	73	72	72	73	74	74	72	72	71	68	65	64	60	61	53	48	47	46	62
48	50	53	54	55	58	64	69	71	73	75	76	78	78	78	76	75	73	69	66	59	67	54	50	50	45	65
54	46	47	50	52	57	62	66	70	73	74	75	76	76	76	73	73	72	70	64	61	60	57	49	47	42	63
60	46	50	50	50	55	62	66	71	72	74	74	74	74	75	72	73	71	68	65	60	67	52	50	46	41	62
66	53	54	52	52	60	64	66	71	71	74	74	75	75	75	73	72	71	68	64	60	53	51	46	44	40	62
72	50	61	61	58	60	68	70	74	76	75	77	77	80	80	80	77	75	70	68	60	60	57	52	48	47	66
78	51	57	57	60	58	74	70	77	73	78	78	77	80	80	77	75	80	70	64	62	58	55	60	47	48	67
84	52	58	60	70	65	65	68	71	70	72	72	75	74	75	70	70	70	68	66	61	57	55	50	46	40	64
90	52	53	50	52	55	63	65	68	67	69	70	71	72	71	71	68	66	63	60	55	52	52	47	44	42	60
96	48	53	48	50	55	62	65	66	67	70	71	71	71	71	67	65	64	61	58	52	52	49	44	40	38	58
102	48	51	47	49	55	58	61	63	65	67	68	68	68	69	66	65	64	62	60	53	50	47	42	38	31	56
108	48	44	48	48	50	56	58	59	60	61	64	64	64	64	64	61	58	55	52	48	43	38	33	29	27	52
114	43	48	40	41	44	47	52	56	58	59	58	60	63	63	61	60	56	51	49	45	37	33	26	24	25	48
120	30	25	32	33	38	38	38	42	48	53	55	55	57	60	53	51	52	47	42	25	28	25	21	10	03	39
Average.	48	49	50	52	55	61	64	67	69	71	71	72	73	73	72	70	68	65	63	57	55	50	46	43	40	

determined by weight. Information on actual results over the range of 22 S.W.G. to 18 S.W.G. is lacking, but some evidence is available on thicker sheets.

Tables 2 and 3 give the results of measurements obtained by cutting up two sheets, each 10ft. by 6ft., the one 16 S.W.G. and the other 14 S.W.G.

The main points are extracted below:—

Sheet gauge	16 S.W.G.
Nominal thickness ...	0.064in.
Specification limits ...	− 0.004 + 0.006
Actual limits	+ 0.001 + 0.006
Mean thickness	0.0685
Per cent. over nominal ...	7%
Limits on mean thickness	− 0.0035 + 0.015
Sheet gauge	14 S.W.G.
Nominal thickness ...	0.080in.
Specification limits ...	− 0.005 + 0.006
Actual limits	+ 0.001 + 0.008
Mean thickness	0.086
Per cent. over nominal ...	7½%
Limits on mean thickness	− 0.005 + 0.002

Whereas the specification limits permit on overall variation of approximately 15 per cent., 92 per cent. of the 16 S.W.G. falls within 0.0685 ± 2 per cent., and 96 per cent. of the 14 S.W.G. within 0.086 ± 2 per cent. If the mean thicknesses of these two sheets are typical, as 40 per cent. of the structure is built from alloy sheet, then we are discounting 1 per cent. of the all-up weight of the aeroplane.

If we have to put up with existing sheet

rolling equipment and technique, then we should change the working limits. It seems probable that −6 per cent. +4 per cent. would be both practicable and possible. Obviously any mean setting of the rolling mill is possible. The adoption of a lower minus limit would only affect the corners of the sheet. This could be catered for in design by local reinforcement and by local boosting of joint attachments. In extreme cases a strip off the end of the sheet would have to be cut off. This is frequently done anyhow as frame or rib spacing rarely exactly fits the length of sheet as produced.

The adaptation of such revised limits would be to transfer 0.5 per cent. of the all-up weight from surplus metal to useful load. It must be admitted that this method amounts to "faking." Ideally the proper solution should be obtained by improving the manufacturing technique. This would, of course, cost a lot of money. It would not be easy to find out how much it costs to remove the last 0.5 per cent. of the all-up weight from machined fittings. Certainly it represents a considerable proportion of the total and this outlay reappears in each aircraft.

Another feature joins issue with the demand for closer sheet tolerances. The design of wing structures for high speed aircraft is undergoing a revolutionary change. Aerodynamic requirements demand a smooth and flush exterior. A sudden step of the order of 0.001in. can be quite serious, anything appreciably more may completely nullify the efforts of the designer.

Where two or more sheets meet at a joint and are joined together by a butt strap, if the thickness of each sheet is varying one from the other and also along their own edges, then a flush joint is very difficult if not impossible to produce. The complexity of achieving a smooth exterior by fitting shims can well be imagined. The alternative is filling, painting and rubbing down, a very long and expensive procedure. This method also involves great maintenance difficulties. This effort should be made at the beginning, when the sheet is being produced, and not at the end when the aeroplane is finished.

Thus it can be seen that modern requirements demand closer control over the production of aluminium alloy sheet, both for the "weight lifters" where surplus material has serious economic consequences, and also for high speed aircraft where a smooth finish is essential for performance.

Conclusions.

The progress of research and development on aircraft structures in recent years has produced a situation where certain defects, both technical and practical, in the materials of construction, have increased in significance.

It is proposed that:—

1. The scope of the routine testing of materials should be extended so as to permit a balanced assessment of specification strength values. This valuation should take into account the gain in the operational efficiency of aircraft resulting from the raising of the minimum acceptable stresses at the cost of increased scrap.

2. The behaviour of materials in compression is best represented by a curve of the ratio of the stress to the tangent modulus plotted against stress. As a spot check the 0.1 per cent. proof stress is a better indication than the 0.2 per cent. proof stress.

3. A complete revision of the maximum acceptable tolerances of sheet material is necessary. Until such time as improved rolling mill equipment becomes available, the limits should be narrowed with a strong bias towards nominal average thickness, i.e., with unequal bi-lateral tolerances. This procedure would be quite safe owing to the very local nature of the low spots which could be catered for in design.

4. It is suggested that any increased cost of materials consequent to the changes would be economically sound from the operations point of view.

THE ROYAL AERONAUTICAL SOCIETY

THEOREMS FOR THE SYNTHESIS OF SIMPLY-STIFF FRAMEWORKS

by

H. Roxbee Cox, Ph.D., B.Sc., D.I.C., F.R.Ae.S., A.F.I.Ae.S.

Dr. H. Roxbee Cox is the Chairman and Managing Director of Power Jets (Research and Development) Limited and Consultant to the Air Registration Board. In recent years, in his present position and previously as Director of Special Projects in the M.A.P., he has been closely concerned with gas turbines and jet propulsion, but has always maintained his interest in aerodynamics, structures and civil aviation. He gave the Wilbur Wright Memorial Lecture in 1940.

§1. Systematic knowledge of the theorems available for building statically determinate frameworks appears to be restricted in this country to a very small circle. Many engineers are content with the knowledge that a simply-stiff plane framework can be produced by attaching a joint O by bars OA, OB to joints A and B of a simply-stiff plane framework; and that a simply-stiff space framework can be produced by attaching a joint O by bars OA, OB, OC to joints A, B and C of a simply-stiff space framework. By these simple means, two- and three-dimensional simply-stiff frameworks can be built up respectively from the basic triangle and basic tetrahedron.

§2. Most textbooks give no other rules of synthesis, and are content to give as "proofs" of the relationships existing between the number of joints j and the number of bars m of a simply-stiff framework ($m=2j-3$ in the two-dimensional case and $m=3j-6$ in the three-dimensional case) the obvious inferences of these relationships from the system of synthesis just described.

Students soon become aware that these relationships are true for simply-stiff frameworks which cannot be developed by these simple rules, and, confronted with such a structure, correctly rely upon the fact that if the usual graphical or algebraic methods of "stressing" non-redundant frameworks give a unique solution, the framework is simply-stiff.

This method of testing is frequently laborious however, and moreover, without more advanced equipment or an unusual degree of intuition, the engineer is likely to be restricted to a somewhat inelegant monotony in his structural devices.

The popularity of stressed-skin constructions may tempt the modern aeronautical engineer to feel that he can safely do without theorems on the disposition of bars in frameworks. Any who have succumbed to this temptation and have read so far as this need read no further. But those who have struggled with complex engine mountings and intricate undercarriage structures, or who are employed by firms which use frameworks for the main structures of some of their designs (e.g., Vickers, Martin-Baker), or who believe that framework systems may provide the most economical structures for some of the aeroplanes of the future, may find the rest of these notes of interest and, possibly, of value.

§3. In what follows, I give six theorems for the synthesis of simply-stiff space frame-

Paper received October, 1944.

works. In the cases of two of them, no formal proofs are necessary for their acceptance. In the cases of three of the others, I indicate where the proofs may be found. The remaining theorem, though of a very simple nature, has not to the best of my knowledge previously been stated. This I prove in an informal manner. I also indicate, by reference to the ground not covered by the theorems stated, the fruitful field that exists for new discoveries in framework theory, a field in which I hope that more investigators with a taste for this not unattractive variety of geometry will elect to work.

The theorems that follow are all for space frameworks. Where corresponding theorems for plane frameworks exist, they can readily be deduced.

§4. A few special terms are used. Three bars meeting at a point are referred to as a *trio*, four as a *quartet*, five as a *quintet*, and so on. The joint common to the bars of an *n-et* or *polyet* is called its *vertex*, and the ends of the bars remote from the vertex are referred to as the *feet* of the n-et.

§5. The first theorem[1] is no more than a restatement in terms of frameworks of the conditions of equilibrium of a rigid body. It is

Theorem I.

A simply-stiff space framework will be formed if two simply-stiff frameworks A and B are connected by

(*a*) *coalescing a bar of A with a bar of B and introducing one bar between a joint of A and a joint of B, neither of which is at an end of the common bar,*

or (*b*) *coalescing a joint of A with a joint of B and introducing three bars so that on each framework three ends are distributed between two or three joints other than the common joint,*

or (*c*) *coalescing no bars or joints and introducing six bars so that on each framework six ends are distributed between more than two joints with not more than three at a joint.*

§6. The second theorem, included for completeness, corresponds to a statement of the conditions of equilbrium of a point in space and is the familiar rule referred to in §1. It is

Theorem II.

If to a given simply-stiff space framework an additional joint is attached by a trio with feet at joints of the framework, the result is a simply-stiff framework.

§7. With the next theorem we reach less familiar ground. It is

Theorem III.

If in a simply-stiff space framework the bar between any two joints is replaced by a quartet with feet at these two joints and at two other joints of the framework, the resulting framework is simply-stiff.

This theorem,[1,2] originally given by Henneberg, is illustrated by the very simple example of Fig. 1. From the double tetrahedral framework (a) the bar BD is removed and replaced by the quartet O. ABED to produce the octahedral framework (b). It should be noted that (b) could not have been developed by any application of Theorem II.

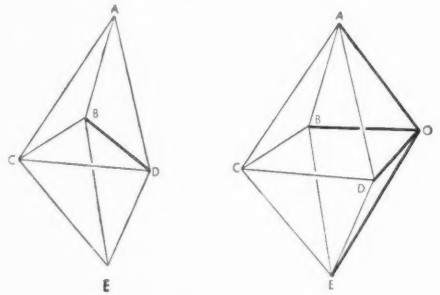


Fig. 1.

§8. Theorem III related to the removal of one bar and its replacement by a quartet. The next theorem relates to the removal of two bars and their replacement by a quintet. The original statement of it was due to Henneberg, but the more precise statement

below is based on the enunciation of Pollaczek-Geiringer.[2] It is

Theorem IV.

If in a simply-stiff space framework

(*a*) *two bars having no joint in common are replaced by a quintet with four of its feet at the joints originally joined by the members and the other foot at any joint of the framework,*

or (*b*) *two bars of a quartet at a joint* (*at which other bars may be meeting*) *are replaced by a quintet with feet at the vertex and feet of the original quartet,*

the resulting framework is simply-stiff.

Illustrating the first alternative in the theorem, in Fig. 2 two bars AB and EF of the framework (a) are replaced by the quintet O. ABEFD to produce the framework (b).

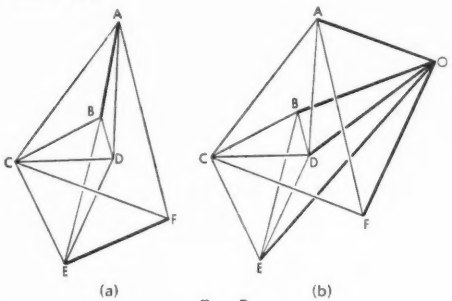


Fig. 2.

Illustrating the second alternative, in Fig. 3 two bars AF and AE of the framework (a), which form part of the quartet A. CFED are replaced by the quintet O. ACFED to produce the framework (b).

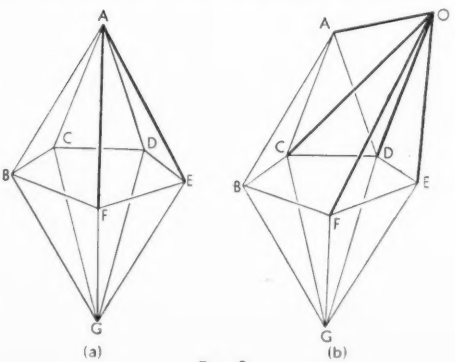


Fig. 3.

§9. From the nature of Theorems II, III and IV, it might be expected that there would follow theorems dealing with the replacement of three bars by a sextet, the replacement of four bars by a septet, and so on. No general theorems on these lines are known to the writer, but there appear to be no fundamental reasons why they should not be developed. It is, however, possible to state for the popular class of framework built up by the time-honoured method of successively applying Theorem II, a theorem by which any number n of bars appropriately selected may be replaced by an $\overline{n+3}$-et. This is the simple theorem (cf. §3) which has not to my knowledge been stated previously, and I propose to develop it forthwith.

§10. Referring to Fig. 4 (a), starting with the triangle 123, suppose the joint 4 is added by the trio 4.123. Then suppose that the joint 5 is added by the trio 5.234, the joint 6 by the trio 6.125, the joint 7 by the trio 7.346. There is no significance in the choices of trio feet made; different choices would have served equally well.

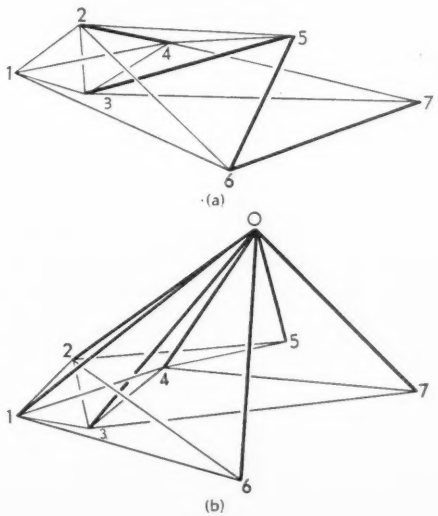


Fig. 4.

Now let us begin the building-up process again. First of all, a trio **0.123** is attached to the basic triangle as in Fig. 4 (b). Now, to locate the joint **4** we choose to use any two of the bars previously used together with a bar from O. Let us adopt the trio **4.013**, realising that **4.012** and **4.023** would have been equally admissible, as would, of course, the original choice of **4.123**.

To locate the joint **5**, we can use the trio **5.024**, though, as before, three other possibilities are available.

Proceeding in this way, joints **6** and **7** are located respectively by the trios **6.012** and **7.034**.

For the purpose of locating the joints **4**, **5**, **6**, **7** relative to the basic triangle the two processes described are equivalent, and the framework (b) can be obtained by replacing in (a) the bars **24**, **35**, **56**, **67** by the septet **0.1234567**. It is evident that any or all of the bars replaced could have been left in position and the septet reduced to a sextet, quintet, quartet or trio, as the case might have been. Also, it is evident that we could have started with a basic structure other than a triangle from which to begin the processes of synthesis described. With these facts in mind, the demonstration given leads to

Theorem V.

If in a simply-stiff space framework built up from a basic framework by the successive addition of trios, one bar is taken from each of any number of the trios, and these bars are replaced by a polyet with three feet on joints of the basic framework and the other feet at the vertices of the trios despoiled, the resulting framework is simply-stiff.

§11. The demonstration has led to a rule for the replacement of bars by a polyet with its vertex external to the original framework. In certain circumstances, however, it may be preferable to choose for the vertex of the polyet a joint of the basic framework. The polyet will then have as many bars as there are bars replaced, instead of three more as in the case of Theorem V.

When applying this theorem, the only safe course is first to number the joints of the framework to be modified in an order in which they can be reached by the process of the successive addition of trios. Then when a bar between two joints is removed, one foot of the polyet must be placed at the joint bearing the *higher* number.

§12. There is one more theorem[1] on the replacement of bars by a polyet in which the selection of bars to be replaced is restricted. It is

Theorem VI.

If in a simply-stiff space framework, n particular joints are braced together by an arrangement of bars which includes a polygon embracing the joints and which, if projected on to a plane, would represent a simply-stiff plane framework, then a simply-stiff space framework results if the n - 3 of these bars which do not form part of the polygon are removed and replaced by an n-et with feet at the n joints.

In illustration of the application of this

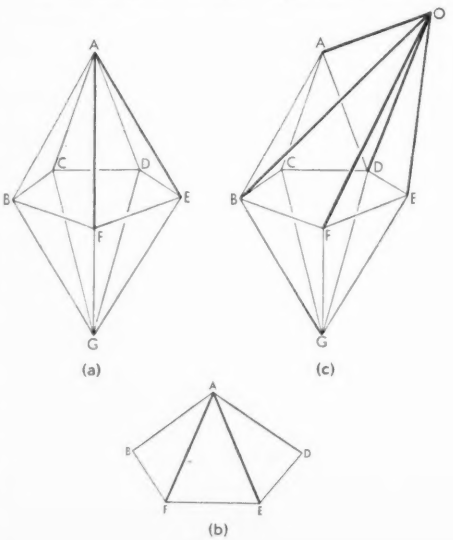


Fig. 5.

theorem, consider Fig. 5 (a), which is the same as Fig. 3 (a). Suppose, as in the illustration of the second part of Theorem IV, AF and AE are to be replaced. Applying Theorem VI, these two bars are regarded as part of the braced pentagon ABFED reproduced as a plane figure in Fig. 5 (b), and the theorem requires their replacement by the quintet O. ABFED.

In Fig. 3, the same bars are replaced by the quintet O. ACFED. It should be noted that in the illustration by Fig. 3 of Theorem IV, the quartet A. BFED could have been chosen in Fig. 3 (a) instead of A. CFED. Had this been done, Theorems IV and VI would have led to identical results; that is, Figs. 3 (b) and 5 (c) would have been identical.

§13. This note is intended as a very brief introduction to advanced framework theory. It is very far from being a résumé of existing knowledge, and no attempt has been made to provide a bibliography, though additional theorems of interest will be found in the references quoted.

The further intention of the note is, as has already been indicated, to draw attention to the possible existence of the series of theorems of which the first three terms are Theorems II, III and IV above. If Theorem V could be completely generalised to deal with the replacement of any number of bars arbitrarily chosen, one grand theorem would replace the series. This is unlikely of early achievement. It is suggested, however, that studies directed to the extension of Theorems V and VI may well be profitable, and may provide clues to the discovery of additional terms in the series of theorems referred to above.

REFERENCES.

1. H. Roxbee Cox. Proc. London Math. Soc. (2), 40 (1936), 203-216.
2. H. Pollaczek-Geiringer. Zeitschrift fur angewandte Math., 12 (1932), 369-376.
3. H. Roxbee Cox. Jour. London Math. Soc., 18 (1943), 20-23.
4. J. Clerk Maxwell. Trans. Roy. Soc. of Edinburgh, XXVI (1870). Also Collected Papers XXXIX.

DESIGN FACTORS OF CIVIL AIRCRAFT AFFECTING THE OPERATING COST

by

R. K. Pierson, C.B.E., B.Sc., A.M.Inst.C.E., F.R.Ae.S.

R. K. Pierson, the chief designer at Vickers (Aviation) Ltd., joined the Vickers Aviation Department in 1911 and became qualified as a pilot in 1913, in which year he was elected an Associate Fellow. Mr. Pierson was the designer of the Vickers Vimy, the first machine to fly the Atlantic non-stop, and has been designing large machines ever since. He was elected a Fellow in 1926.

THE designer of transport aircraft can play a very important rôle in improving the economic efficiency of air transport and the following analysis is devoted to a review of some calculations illustrating this aspect of aircraft design.

Economic efficiency must not be obtained at the expense of other necessary qualities, and it would be as well to touch briefly on some of these before considering cost alone.

(*a*) *Safety and Comfort.*

American experience shows these factors to be as important as any. The introduction of a type of aircraft with a good reputation in these respects leads to remarkable popularity.

(*b*) *Speed.*

This, the main advantage of air over sea, rail and road transport (reducing a journey of weeks to days, and of days to hours), has a very different importance when reduced to the possible saving of a few further hours or minutes. For usual aircraft engine combinations, it will probably be found worthwhile to increase the cruising speed to that at which economic and safe continuous running of the engines is not exceeded. Thus, for the machine " X " described later (see Fig. 11), this speed is rather less than 250 m.p.h. at mean flying weight. To increase the cruising speed beyond 250 m.p.h. without further design improvement would entail larger engines at which point the cost per ton-mile will begin to mount very rapidly indeed.

(*c*) *Convenience.*

This is very much bound up with the extent to which the airline is willing to run aircraft incompletely loaded. This factor has led to the introduction of fairly small aircraft on the internal lines of the U.S A., allowing a more frequent service and a greater allocation of aircraft to non-stop flights. The entirely different conditions on such routes as the trans-Atlantic make larger aircraft economically sound.

The necessity for operating aircraft loaded at less than their capacity has a very important effect on the cost per paying ton-mile of the items of group II discussed in Section I.

For the purpose of this analysis, a load factor (percentage of pay load capacity occupied by paying load) of 80 per cent. has been assumed, but it should be noted that even this figure is seldom obtained. American internal airline statistics for 1938-1942 show

Paper received October, 1944.

values usually in the region of 60 per cent., although there is a tendency to improve in the later years, due possibly to increased demand and reduced supply caused by the war. Some routes show factors as low as 20 per cent.

It is obvious from Fig. 1 that suitable planning to ensure high load factors can have as much effect at present as the efforts of the aircraft manufacturers.

SECTION I.

Basis for Cost Estimation.

For convenience the costs are divided into two main groups:—

Group I.—*Those controlled almost entirely by the airline operator,* depending largely on the type of route and frequency of service.

Group II.—*Those which are in any way controlled by the aircraft designer.* As it is impossible to draw a clear line between the two groups, all border-line items are included in this group to provide a complete picture.

Group I Costs.

There is little purpose in dealing extensively with these beyond saying that they include such items as:—

General administrative costs, including the salaries of the general manager, air superintendent, commercial manager, etc.; accountancy, technical office staff, operating managers, engineering superintendents and storekeepers; booking agents, commission, agency fees and publicity charges; maintenance, insurance and depreciation of plant and commercial premises; insurance and carriage of spares; legal and auditorial fees; housing and landing charges; meals, transport, and accommodation of passengers; expense of caring for passengers on interrupted trips; interest on capital and other miscellaneous charges.

It might be mentioned in passing, however, that an analysis of the statistics of the internal routes of the U.S.A. over the period 1938-1942 shows these Group I costs to be decreasing steadily, reaching a figure of about one shilling and sixpence per paying ton-mile in 1942.

Summary of Assumptions for Group II Costs.

Fuel and Oil.

An average value of 2/- per gallon, including duty, has been assumed for fuel.

Oil is taken as one-tenth of the fuel cost equivalent to about 8/- per gallon for usual values of the relative consumption.

Crew.

Captain + co-pilot + flight engineer + two cabin attendants, with a total cost, including insurance and accommodation, of 0.42 shillings per mile at 200 m.p.h. This rate is assumed to be inversely proportional to the square root of the speed (i.e., the cost per hour directly proportional to the square root of the speed). This is a good approximation to the usual schemes of fixed salaries + flying pay.

Depreciation, Maintenance, Repair and Insurance of Complete Aircraft.

The form of the following laws has been derived from a detailed investigation of such considerations as development, experimental and tooling costs, installation requirements, factors influencing repair and maintenance costs, obsolescence, utilisation, flying conditions, types of construction, etc. The constants in the equations are chosen to agree as far as possible with the data at present available:—

Airframe Repairs—		
Material	$0.46 \times 10^{-3}\ W^{0.8}\ V^{-0.7}$	shillings per mile
Labour	$0.79 \times 10^{-3}\ W^{0.8}\ V^{-0.7}$	,, ,,
Airframe Maintenance—		
Material	$0.62 \times 10^{-3}\ W^{0.8}\ V^{-0.7}$	,, ,,
Labour	$1.11 \times 10^{-3}\ W^{0.8}\ V^{-0.7}$	,, ,,
Engine and Propeller Repairs—		
Material	$0.189\ N.P^{0.7}\ V^{-1.0}$	,, ,,
Labour	$0.167\ N.P^{0.7}\ V^{-1.0}$	,, ,,

Engine and Propeller Maintenance—
Material $0.131\ N.P^{0.7}\ V^{-1.0}$,, ,,
Labour $0.074\ N.P^{0.7}\ V^{-1.0}$,, ,,
Airframe Obsolescence—
$0.152 \times 10^{-4}\ W^{1.2}\ V^{-0.5}$,, ,,
Engine and Propeller Obsolescence—
$0.71 \times 10^{-3}\ N.P\ V^{-0.5}$,, ,,
Wireless and Instrument Repair and Obsolescence—
$0.006\ W^{0.5}\ V^{-0.6}$,, ,,
Insurance—
8 per cent. of initial cost p.a.

where W = all-up weight of the aircraft in pounds.
V = cruising speed in m.p.h.
P = cruising horse-power used per engine.
N = number of engines.

The absolute values of the costs must not be too much relied upon as there is no data available for fully developed British airlines. It is thought, however, that they are of sufficient accuracy to gauge the relative merits of design features.

A " break down " of the various cost items as calculated for the machine " X " is shown in Fig. 2 to illustrate the relative importance of the various items and the return to be expected from a reduction in the price of fuel, airframe cost, etc.

SECTION II.

Estimated Costs for a Typical Aircraft.

The effect on cost of various design features has been calculated for a machine of typical present day design. The general conclusions derived from each graph will apply approximately to almost any modern machine, although the accurate variation can be obtained by a similar calculation for a particular aircraft. This specimen machine is designated " machine X " and its leading dimensions are listed below.

" Machine X " basic features remaining constant except as stated:—

Take-off weight	100,000 lb.
Wing area	2,000 sq. ft.
Wing loading at take-off ...	50 lb./sq. ft.
Aspect ratio	10
Span	141.4 ft.
Disposable load	38,000 lb.
Rated b.h.p.	4 × 2250
Maximum cruising power for continuous running ...	60 per cent. of rated
Power loading (rated power)	10 lb./h.p.
C_D (wing + tail unit) ...	.0095
C_D (fuselage, nacelles, etc.)	.0130
Induced drag factor, $1/e$ ...	1.25
Operating altitude	10,000 ft.
Mean propeller efficiency ...	0.80
Specific consumption (including an allowance for oil)	0.475 lb./b.h.p./hr.
Load factor	80 per cent.
Fuel reserve for 45 m.p.h. headwind + 2 hours cruise.	

To allow for warming-up, take-off and climb, net effect of winds, deviation from course, etc., the equivalent still air distance for which fuel is used is taken as 1.02 × great circle distance between termini + 60 miles.

Fig. 3 to Fig. 12, showing the effect of a number of design variations require little further explanation, but a few additional notes and a discussion are added below.

General Note.

To show clearly the direct effect of each design variation, the curves in each case are for a change of the factor under consideration alone, assuming that nothing else alters. In practice some of these changes will necessarily involve other changes for a given design. Most of these combined variations can be obtained approximately by a combination of more than one graph. This procedure has the additional advantage of avoiding the dispute that often arises as to the relative magnitude of such combined variations, e.g., Fig. 9 will show the purely aerodynamic effect of an increase in aspect ratio assuming that everything else (the disposable load in particular) is unaltered. The penalty due to structure weight increase (according to the reader's own views on this subject) can then be read from Fig. 3.

Fig. 1.—Load factor has already been discussed in the introduction. It has an almost direct inverse effect on cost per paying ton-mile, although a reduced load factor is partly compensated by reduced fuel con-

sumption and engine power due to reduced flying weight.

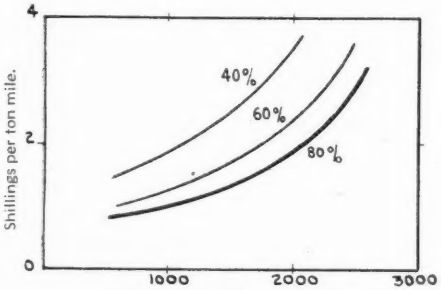


Fig. 1.—Effect of Load Factor on Group II costs.

Fig. 2.—Group I costs (an arbitrary value of one shilling per ton-mile) have been included in this graph to give it proportion. Also, many of the smaller items have been combined to avoid confusion (see page 31).

Fig. 3.—Disposable load is defined as pay load + fuel, tankage and oil weight. 34 per cent.—42 per cent. includes the majority of present-day landplane civil aircraft. Increase in disposable load is obviously obtainable by saving in structural, power plant and other tare weight.

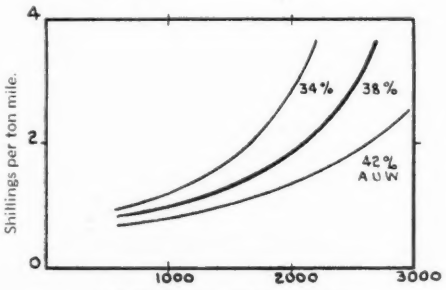


Fig. 3.—Effect of Disposable Load Group II costs.

[Figs. 4 and 5.—The usual drag equation of the form $C_D = C_{Dz} + C_L^2/\pi Ae$ is assumed, where $1/e$ is often termed the "induced drag" factor, although as explained below, most of the difference between $1/e = 1.0$ and its actual value is usually but a small part extra induced drag.]

Fig. 4.—Reducing the basic drag in the above equation has a very beneficial effect

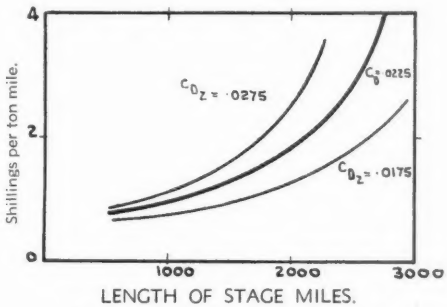


Fig. 4.—Effect of Drag at Zero Lift Group II costs.

on cruising efficiency, especially at the higher cruising speeds. $C_{Dz} = 0.0225$ represents a good average value for modern civil aircraft of this size and proportions. $C_{Dz} = 0.0175$ is probably about the best that can be obtained with orthodox lay-outs. $C_{Dz} = 0.0275$ represents a poorer landplane.

Fig. 5.—The induced drag factor represents the increase of the slope of the drag-lift squared curve over that for the induced drag of an elliptically loaded wing. $1/e = 1.0$

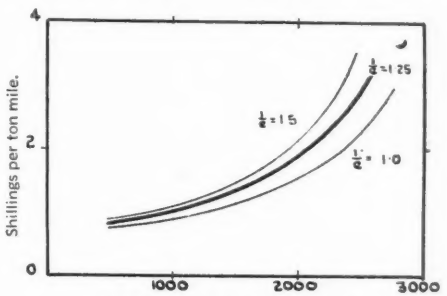


Fig. 5.—Effect of Induced Drag Factor, $\frac{1}{e}$ on Group II costs.

is an ideal figure since increases of wing profile drag, etc., with incidence are included in addition to any increase in induced drag above the ideal. $1/e = 1.25$ represents a common value, but $1/e = 1.5$ is possible in a bad case where, for example, nacelles and fuselage badly upset the lift distribution. An

increase in e is, of course, equivalent to an increase in aspect ratio, the product Ae often being termed the equivalent aspect ratio.

Fig. 6.—80 per cent. is a good mean value for the propulsive efficiency and 75 per cent. to 85 per cent. probably represents the range for present day applications.

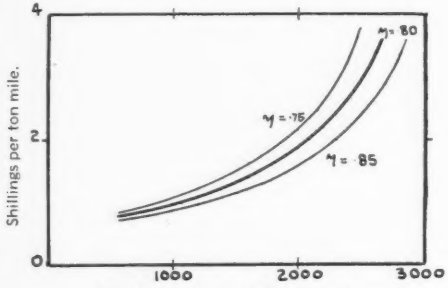


Fig. 6.—Effect of Propeller Efficiency on Group II costs.

Fig. 7.—The carrying of a large fuel reserve increases the cost per ton-mile considerably for long stages. The amount is a matter for Government ruling, but it shows that a highly efficient meteorological service is well worth the cost. The reserve for a 45 m.p.h. headwind + 2 hours cruising is rather an extreme case.

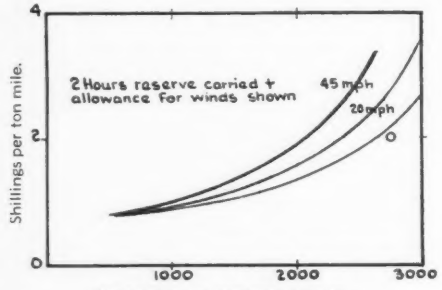


Fig. 7.—Effect of Fuel Reserve Carried on Group II costs.

Fig. 8.—.475-.525 lb./h.p. hr., which includes an allowance for oil, covers the economic condition of most present day engines. .425 lb./h.p. hr. represents a possible reduction.

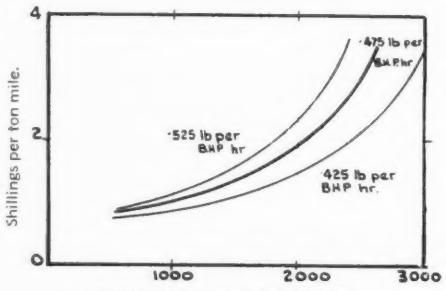


Fig. 8.—Effect of Specific Fuel Consumption on Group II costs.

Fig. 9.—As noted above, the effect shown is the purely aerodynamic.

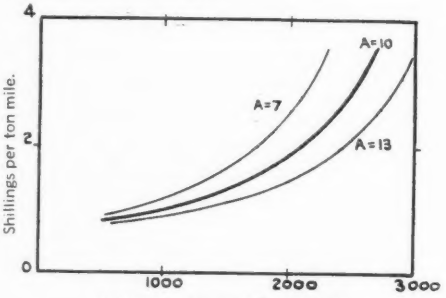


Fig. 9.—Effect of Aspect Ratio on Group II costs.

Fig. 10.—More exactly this figure should be labelled "effect of variation of wing area." The remainder of the machine, apart from the tail surfaces, is assumed unchanged. The resulting aerodynamic effect on cruising performance is small and

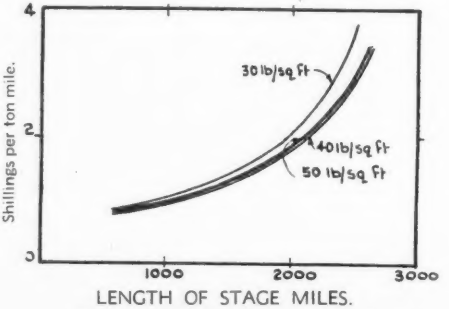


Fig. 10.—Effect of Wing Loading on Group II costs.

is over-ridden in practice by structural, take-off and landing performance considerations, etc.

Fig. 11.—The effect of increase of speed within the normal cruising range is quite small except for long stages. Further speed increase beyond that shown will require larger engines at which the cost per ton-mile will begin to increase rapidly.

Fig. 12.—The curves are labelled pre- and post-war as they are more or less a transition from typical designs of a year or

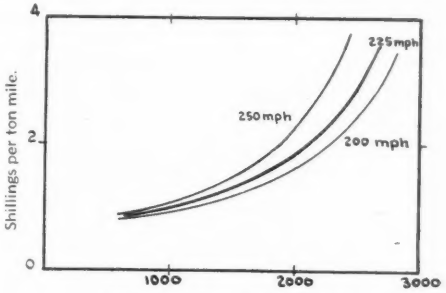


Fig. 11.—Effect of Cruising Speed on Group II costs.

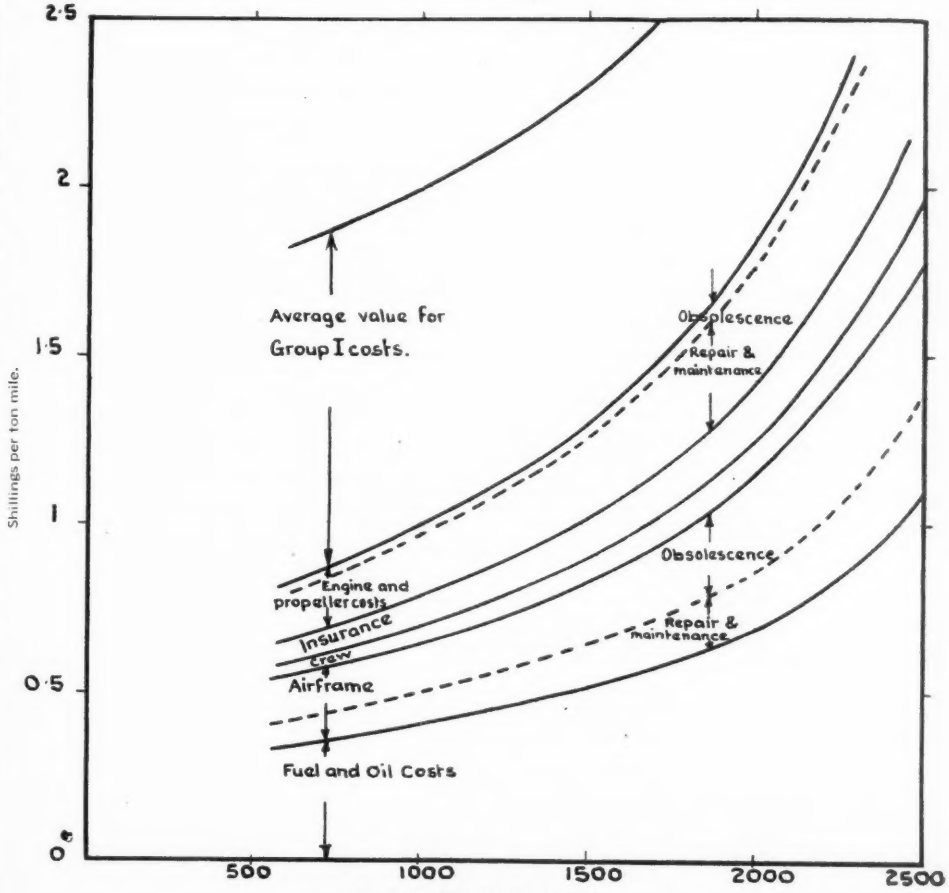


Fig. 2.—Breakdown of Total Costs [Group 1 + Group 2]

two before the war to a year or two after. The astonishing change due to a number of improvements shows how important a rôle the aircraft designer can play in the economy of civil aviation.

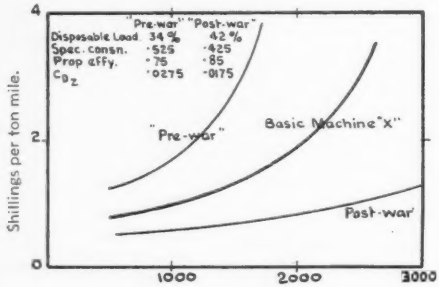


Fig. 12.—Group II costs.

Conclusions.

1. Individual conclusions can be read from the graphs.

2. The pay load is the main factor affecting the cost per ton-mile, although the amount saved by a given increase in the pay load depends on the manner in which the latter is obtained.

Aerodynamic refinements (increased propeller efficiency, reduced C_{D_Z} and $1/e$) entail a saving in the horse-power required for cruising. This implies a saving in operating cost per mile both for fuel and engine costs.

Pure weight saving by structural or other improvement does not give this bonus.

Improvement in specific consumptions gives a saving in fuel cost per mile.

These effects are secondary except perhaps for the saving in fuel cost at the smaller stages.

To a first approximation, therefore, pay load is the measure of the economic efficiency of an aircraft so long as it is not obtained to the detriment of other essential qualities.

The question of aspect ratio and wing loading is so much involved with structure weight, structural and lay-out considerations, take-off and landing requirements, etc., as to require a much more elaborate analysis.

Acknowledgments.

The author is much indebted to Dr. E. P. Warner, Vice-Chairman, Civil Aeronautics Board, U.S.A., whose authoritative Wilbur Wright Lecture of 1943 on "Post-War Transport Aircraft" has been freely drawn upon. He also wishes to thank Mr. R. F. Creasey, B.Sc., for his help in the preparation of the manuscript.

REVIEWS

Per Ardua. The rise of British Air Power, 1911-1939. Hilary St. George Saunders. Oxford University Press, 1944. 15s. net.

There is something in the air which is an inspiration to writers. Some of the finest writers of modern times, indeed, have had that inspiration. We live in the pioneering of a new field of adventure where romance is not yet so commonplace as to be no longer a subject of newspaper headlines. As one who has been closely connected with aviation for the past thirty years, the reviewer confidently predicts that the next thirty will be years of high adventure, of such progress and such opportunity, that if he were thirty years younger he would be more madly air-minded than he now is.

Thirty-odd years ago A. V. Roe, Sopwith, Handley Page, Blackburn, Short, Camm, Gouge, Pierson, Fedden, Hives and endless others were unknown names in this country among designers; Moore-Brabazon, Hawker, Cobham, de Havilland (designer as well), Brooke-Popham, Trenchard—one could fill a column with their names—were hardly known, except to the few. Mitchell, the ever-to-be-remembered designer of the Spitfire, was still a boy at school. In another thirty years there will be another set of names, another thirty years of romance in aviation history to be written.

Mr. St. George Saunders has condensed into some three hundred pages an excellent summary of the growth of the most efficient air force the world has yet seen, one which in its first few years of history has left its mark on history for all time. Sir Walter Raleigh and H. A. Jones in the six-volume *The War in the Air* have covered the history of the war in the air in 1914-18 so well that there is little more to be said from the purely historical point of view. Mr. St. George Saunders acknowledges his indebtedness to that history and to many who have helped him with the story from 1920-1939. The present volume, however, has more of the human touch.

One relishes, for example, the author's description of Lord Fisher " endowed with the cunning of the fox, the hide and memory of the elephant, and the resolution of the lion . . . this fierce old man, whose fiery tongue was the joy and terror alike of his equals and his subordinates"; and the odd note about submarine spotting: " Occasionally, the behaviour of gulls betrayed the U-boat, but it was soon found that for some reason, familiarity perhaps, the birds ignored periscopes in the North Sea while following with dogged persistence any which moved through the waters of the Irish Channel."

There is, too, the story which might have been written by A. A. Milne or A. P. Herbert of Lieutenants Scholtz and Wookey, of No. 11 Squadron, who were shot down. Pamphlets urging German soldiers to desert were found in their Bristol aircraft, and the Germans sentenced them to ten years' penal servitude. The threat of reprisals by the British Government obtained their release, but it was ruled by the Chief of the General Staff that in future no propaganda literature should be released from aeroplanes, but only from balloons!

It is worth while recalling, as the author has recalled, at the present moment, Foch's dictum about the use of the air forces when he took over supreme command: " The essential condition of success is the concentration of every resource of the British and French bombing formations on such few of the most important of the enemy's railway junctions as it may be possible to put out of action with certainty, and to keep out of action"; and he added: " The first duty of fighting aeroplanes is to assist the troops on the ground by incessant attacking with bombs and machine-guns on columns, concentrations or bivouacs."

The author of *Per Ardua* has concentrated more on the years to 1919 than to those from 1920 to 1939, those years in which he says: "Yet despite every setback, every disappointment, every misfortune which the years 1918 to 1939 held for it, it was too robust to perish." Here is told that bitter story of endeavour. Some day it is hoped that these years will be told in full, and credit given in full to those far-sighted designers of aircraft and aircraft engines, and all the accessories which went to make up the machine; to those few air-minded politicians who joined in the battle for air superiority; and to those devoted civil servants and much-maligned Air Marshals who struggled to provide the industry with the facilities for design, construction and research which were all too meanly denied them by the Governments of those fateful years.

The reviewer has only two small comments to make. The first Englishman to fly was the present Lord Brabazon. The claims of A. V. Roe were examined by a Committee of the Royal Aero Club and were not accepted.

In the Chronology at the end of the book the mistake is repeated. Also in the Chronology the date of the founding of the Aero Club is given (1901). The author may be forgiven that he had not heard that the honour of being the oldest aeronautical body in the world is held by the Royal Aeronautical Society, which was founded on January 12th, 1866.

That fact might very well begin the Chronology in the next edition of *Per Ardua*.

Practical Analytic Geometry, with Applications to Aircraft. Roy A. Liming. The MacMillan Company, New York and London, 1944. $4.50.

This is a book which has long been wanted and one which should prove of real practical value to the aircraft designer, draughtsman and stressman. It is the practical application of analytic geometry to the solution of everyday aircraft engineering problems, especially those concerned with lofting and tooling. The widespread increase in lofting methods, indeed, makes necessary a thorough understanding of the uses of analytic geometry in the accurate solution of the problems which arise in practice, with the consequent necessity for accuracy of tooling.

The book is divided into three main sections. The first deals with Applied Plane Analytic Geometry, the second with Applied Solid Analytic Geometry, and the third with the Analytic Analysis of Curves Used in Lofting.

Apart from the clear explanations in the text, the great value of this book is in its wide use of practical examples which provide the living flesh to the dry bones of the formulæ used.

This is, indeed, a first-class practical book and can be unreservedly recommended to all who come within that wide and rather vague category of the aircraft engineers. There are few aircraft engineers, however, who will not learn and benefit from it.

ABSTRACTS

Abstracts from the Scientific and Technical Press are issued by the Directorates of Scientific Research and Technical Development, Ministry of Aircraft Production.

Documentation. (W. Rahts and H. Joachim, Z.V.D.I., Vol. 88 (1944), pp. 125-126.) (127/1 Germany.)

Documentation implies the collection, classification and utilisation of documents of all kinds. The term document in this connection signifies any type of record, and thus besides printed matter includes exhibits in museums, films and gramophone records.

A special Society for Documentation was formed in Germany in 1941 under the auspices of the Ministry of Science and Education. From a preliminary survey of the problem it appears that a single central organisation is impracticable, nor can the methods of classification be made universal. It appears preferable that the various bodies interested in documentation should each set their own house in order, adopting the means of classification most suited for their special needs. The Society will function as a co-ordinating body and arrange for frequent meetings between librarians, abstractors and readers on the one hand, and technical editors, film specialists and museum directors on the other. Standardisation of journals and methods of reproduction will also be considered.

In the case of microfilms the provision of a cheap and efficient projector will be one of the first duties of the Society. Whilst documentation in the field of chemistry leaves little to be desired, the field of general engineering is not in a satisfactory state. The various engineering journals overlap to a considerable extent in their choice of articles, and this needless repetition clutters up the card index without adding anything to the store of knowledge. Any unification in this direction would be well worth while.

The abstracting of engineering articles also presents considerable difficulties, since the same article will appeal to different specialists in different ways. Thus even in the relatively simple case of an article covering an electrically operated crane, the electrical engineer will be interested primarily in the motors, the structural engineer in the design of the frame, whilst the works manager requires details of the loading capacity and ease of operation.

Documentation on Social Sciences has received an important impetus in Germany by the formation of the Central Library of the Institute of Labour of the D.A.F. This library held over 330,000 books in 1942, with a yearly accession of about 10,000 volumes. The classified card index covers more than 300,000 references.

Forestry is also well catered for by the Forestry Institute in Berlin, but much requires still to be done in the field of agriculture, although a start was made as long ago as 1909 by the creation of the International Institute of Agriculture in Rome. The German Ministry of Food has taken active steps to bring documentation on agriculture up to date. A central library of 100,000 volumes has been set up and over 500 journals are periodically reviewed.

A model of documentation is furnished also by the German Patent Office in Berlin. Up to now, most of their labours have been directed towards their special fields of enquiry, but steps are being taken to render their records more generally available to German industry.

As already explained, the German Society of Documentation has been set up to co-ordinate the activities of these various centres of documentation, and a special department

has been set up to pass enquiries for information to the particular centre concerned.

The 10th Anniversary of the Creation of the Central Information Section (Z.W.B.) of the German Air Ministry. (K. Simon, Luftwissen, Vol. 10 (1943), pp. 316-317.) (127/2 Germany.)

The Z.W.B. was originally part of the D.V.L. (German Research Centre at Adlershof, Berlin) but became an independent unit in 1940, working in close conjunction with the Lilienthal Society.

The Central Information Section is responsible for passing on to the industry the results of all research work carried on in the Reich. Great importance is attached to the presentation of the results in a form facilitating their immediate utilisation. This implies in many cases editing the reports, since a research worker is not necessarily a good author. Special importance is attached to work which failed to achieve the final purpose for which it was undertaken. Such work is often regarded as of little importance by the original authors and the recording is apt to be neglected. Nevertheless there have been many instances where difficulties encountered or partial success achieved proved of paramount importance to workers in other fields.

The Z.W.B. is also responsible for the issue of the journal "Luftfahrtforschung" (which is stated to have a greater edition than any other scientific journal of equal standing) and before the war also produced the yearly volumes covering German aeronautical research activities. These volumes, both by the range of articles and high standard achieved, clearly indicated the presence of a competent editorial staff.

During the war, the Z.W.B. has also rendered great service to the German industry by making itself responsible for reprints of standard text-books and books of reference in sufficient numbers to cover requirements.

A large translation section is available which works in close co-operation with similar sections of the German Air Ministry, the German Academy of Aeronautical Research, and any translation sections operated by aircraft firms. In this way a large pool of efficient translators is rendered available and duplication avoided.

Extensive facilities are available for photostat and microfilm work, and copies of any journal or article in the Z.W.B. library can be prepared at short notice.

It is generally agreed that the Z.W.B. has achieved the objects for which it was created, and by the rapid dissemination of up-to-date information in a form suitable for its direct application by the industry has rendered possible notable achievements of the German aircraft and engine industry. Thus the rapid development of the D.B. engine has only been possible by the pooling of the design experience of the German motor industry as a whole. Instead of carrying out documentation as an object in itself, the results are analysed by practical engineering experts before being passed out. The permanent attachment of such a body of experts to any technical library is bound to improve its utility enormously.

On the Flow of Gases through a Nozzle with Velocities exceeding the Speed of Sound. (L. Fox and R. V. Southwell, Proc. Roy. Soc., Series A, Vol. 183, No. 992, 10th August, 1944, pp. 38-53.) (127/3 Great Britain.)

The discharge of gases through convergent-divergent nozzles was investigated as long ago as 1886 by O. Reynolds, who showed that the limiting mass flow is attained when the local velocity of sound is reached in the smallest section. In these circumstances two regimes of flow can exist in the downstream sections of the nozzle.

(*a*) After attaining sonic velocity at the throat, the gas may again contract with increase in pressure and the downstream flow be subsonic.

(*b*) The gas continues to expand, the flow becoming supersonic.

Reynolds assumed that the velocity is distributed uniformly over each cross-section (curvature of streamlines neglected) and in this case the limiting mass flow of both regimes is the same, although of course the exit pressures are different. When an attempt is made to improve the theory by making allowances for streamline curvature, the problem becomes very difficult, even if restricted to two-dimensional flow.

The authors utilise an iterative or strip integration method for this purpose, in which the nozzle is converted into a rectangle by conformal transformation.

The results indicate that the limiting mass flows of the two regimes (*a*) and (*b*) discussed above are not identical, as would be the case if the velocities were truly constant over the sections. The differences are, however, very small, regime (*b*) with supersonic flow exceeding (*a*) by only .045%. Similarly, Reynolds over-estimates the true value for (*a*) by .083%.

The most interesting conclusion from this more accurate investigation is that for maximum flow conditions in the (*a*) regime with subsonic flow both upstream and downstream of the throat, supersonic regions of flow are indicated in two localised regions adjoining the walls at the throat.

From the convergence of the iterative process it appears that irrotational flow is stable from low velocities up to those entailed in the limiting subsonic regime (*a*), but is unstable in the supersonic regime (*b*).

The physical bearing of the work will be discussed in a subsequent paper.

Abstractor's Note.—Accurate flow determinations for nozzles in the supersonic region can also be obtained by the method characteristics developed by Prandtl and Busemann. It is interesting to note that whilst increase in the cross-section of the nozzle beyond the throat necessarily leads to an increase in speed under these conditions, stable supersonic flows can also exist in cylindrical rotor elements if the flow has a rotary component before entry. (See "Present Problems of Flow Research," E. Sorensen, Z.V.D.I., Vol. 88 (1944), pp. 115-119.)

Simplification of Design for Production. The Avoidance of Unnecessary Refinements. (P. Leinweber, Z.V.D.I., Vol. 88 (1944), pp. 121-124.) (127/4 Germany.)

An efficient engineering product should satisfy the requirements for which it has been produced, but all refinements in excess of these should be rigidly excluded. In the case of a watch, for example, the expensive chronometer escapement is only justified in special cases. On the other hand, high quality steel springs should always be fitted. Turning the watch into a piece of jewellery is a departure from efficient design and only justifiable under peace-time conditions. The same applies to the keyless winding mechanism. It is expensive to produce and facilitates the entry of dust. As soon as standardised keys become available, the winding operation can be carried out almost as simply with a considerable saving in materials and cost of manufacture. These remarks apply with special force to war materials which in many cases still incorporate unnecessary refinements. As an example, the author instances the standard German machine gun holding bracket which formerly was provided with an expensive ratchet giving adjustment of a few centimetres by means of a handwheel. This adjustment was rarely used and has now been done away with, thus simplifying the bracket considerably. According to the author, the Soviet military authorities have gone far in simplifying their military equipment in this way without sacrificing striking power.

There are six main headings under which new designs should be examined to ensure that utmost simplification has been achieved.

1. Limitation of requirements to be met by the finished article to bare necessities.
2. Reduction of accuracy and manufacturing limits consistent with facility of replacement.
3. Limitation of surface finish to those parts where high finish or special surface qualities (hardness) are essential. This also applies to anti-corrosive treatment.
4. Limitation of types and far-reaching standardisation of parts.
5. Avoidance of bottlenecks due to specification of materials in short supply or difficult methods of manufacture.

All these points should be borne in mind before the design is actually undertaken, and not be left till a prototype has been constructed.

Close co-operation with specialists is indicated, especially as regards items (4) and (5).

Once an article has gone into wide production, simplification is often difficult to achieve. In this case the advantages due to a saving in material and labour must be carefully weighed up in comparison with a slowing up of production during the changeover period. Nevertheless, the difficulties under which German industry has to operate under present conditions make it urgent that simplifications in the design of products be carried out, and the author impresses all engineers with the importance of this problem.

Inertia Vibrator with Automatically Controlled Out of Balance Force. (H. Roos, L.F.F., Vol. 13 (1936), pp. 69-70.) (127/5 Germany.)

The vibration characteristics of aircraft structural elements are usually investigated by attaching to the part in question a rotary out of balance mass, the speed of which can be varied over wide limits. The disadvantage of this form of vibrator lies in the fact that the excitation force varies as the square of the r.p.m. and may thus induce dangerous amplitudes over the higher frequency range. If, on the other hand, the out of balance mass is reduced, the low frequency amplitudes become too small for routine investigations. To overcome these difficulties, the firm of Junkers have designed a new form of exciter in which the out of balance force, instead of increasing indefinitely with speed of rotation, tends to a finite limit. For this purpose, the single out of balance mass as usually fitted is replaced by two pendular masses supported by bearings placed along a diameter of the rotating disc at equal distances from the centre. Each support incorporates a spiral spring tending to approach the two pendulums to each other, so that with the disc at rest the point of contact of the two pendulum weights lies along a diameter of the disc. Rotation of the disc causes the two pendulums to separate, with the result that the centre of gravity of the pendular system approaches the axis of rotation. (In order to assure stability of operation, the outer bearing shells of the two pendulum supports are provided with intermeshing gear teeth.)

Since at any speed the moment of the centrifugal force must balance that of the control spring, it is easily shown that the out of balance force P (kg.) of such a system is given by

$$P = (2c/a)\ (\alpha + \phi)$$

where c = control spring constant in cm. kg.
a = distance between pendulum supports.
α = initial angular twist of control spring (disc at rest).
ϕ = angular deflection of pendulum from position of rest.

Maximum value of P is thus reached when $\phi = 90 - \delta$

where δ = angle which pendulum makes with contact diameter when disc at rest.

This finite asymptotic value is reached at

infinite angular velocity when the common c.g. coincides with the axis of rotation.

At any other speed of rotation n (r.p.m.), the connection between P and n is given by the equation

$$n = \sqrt{\frac{45000\ P}{Gb \sin (90^\circ + \delta - a + Pa/2c)}}$$

where b = length of pendulum.

G = weight of a single pendulum (kg.),

the other symbols having the same significance as before.

For small values of n, this relationship approximates to the normal square law increase in P. The curve, however, soon exhibits a point of inflexion after which P rapidly approaches a constant value, however high the speed of rotation.

For a particular vibrator designed on these lines, this point of inflexion occurred at about 300 r.p.m., as is shown by the following table:—

n (r.p.m.)	P (kg.)
100	5
200	15
400	44
800	82
1200	92
1600	95
∞	98

Over the speed range 1000 to 2000 r.p.m. or beyond, the exciting force is thus practically constant. It must be remembered, however, that this force rotates in the plane of the disc and has no constant direction in space. If such a unidirectional force is required, a combination of two pendular systems rotating in opposite directions must be employed.

Fatigue Testing Machine for Aircraft Structural Elements. (Junkers Aircraft German Patent No. 744942.) (127/6 Germany.)

The testing machine forming the subject of this patent is characterised by its compactness and light weight, and is thus specially suited for attachment to such aircraft elements which normally are difficult of access. The machine is essentially a vibrator, characterised by the fact that the stress amplitude is maintained constant during the test irrespective of the deflection of the specimen. For this purpose an opposed piston aggregate consisting of two open-ended cylinders and a straight-through connecting rod is employed.

The pistons are caused to oscillate by air pressure, and the resultant vibratory motion is transferred to the specimen under test by attaching one end of the latter to the connecting rod in question whilst the other end is rigidly held.

The special feature of the machine is the fact that the working cylinders are not rigidly fixed to a base plate, but are free to slide under the control of elastic abutments attached to the closed ends.

Confining our attention to one of the piston cylinder units, it is clear that on the admission of compressed air to the cylinder, the piston and cylinder will move in opposite directions, the respective travels depending on the resistance offered by the test specimen (attached to the connecting rod) and the cylinder abutment. Moreover, for a given spring characteristic of the latter, the position of the cylinder corresponding to a given stress in the specimen is fixed. As soon as this position is reached, the cylinder operates a suitable valve mechanism which releases the air pressure and at the same time allows compressed air to enter the second working cylinder which up to then was at atmospheric pressure. The cycle is then repeated, the specimen being strained in the opposite direction. In this manner the specimen is automatically subjected to cyclic stresses of constant amplitude irrespective of the actual piston travel or strain amplitude of the test specimen.

Moreover, for a given abutment elasticity, the frequency of the stress cycle can be varied over wide limits by simply altering the air pressure fed into the system.

The new designations divide the plastics into moulded and laminated products with the following code numbers:—

00 to 999 *Moulded Products.*
2000 to 2999 *Laminated Products.*
00 to 99 Phenol Resins, hot pressed.
00 to 09 without filler.
10 to 29 inorganic filler.
30 to 49 wood filler.
50 to 69 cellulose filler.
70 to 89 textile filler with organic fibres.
90 to 99 other fillers.

The last figure gives an approximate indication of the mechanical properties, 0 showing the lowest and 9 the highest strength in each class of 10 units.

100 to 149 Urea or thiourea.
100 to 109 not used at present.
110 to 119 inorganic filler.
120 to 129 wood filler.
130 to 139 cellulose filler.
140 to 149 not used at present.

Continued on next page

Type Designation of German Plastics with Special Reference to Insulating Materials. New edition. (E.T.Z., Vol. 63 (1942), pp. 267-269, and Vol. 64 (1943), pp. 26-27.) (127 7 Germany.)

Type.		Composition.	Min. Mechanical Properties.			Manufacture.
Old Designation.	New Designation.		Bending Stress Kg./cm.²	Impact cm. Kg./cm.²	Notch cm. Kg./cm.²	
11	11	Phenol resin with inorganic filler.	500	3.5	1.0	Hot press.
11*	11.5		500	3.5	2.0	
12	12		700	15.0	15.0	
M	16					
O	30	Phenol resin with wood flour filler.	600	5.0	1.5	ditto.
O*	30.5					
S	31		700	6.0	1.5	
S*	31.5					
T_1	71	Phenol resin with textile fibre.	600	6.0	6.0	ditto.
T_2	74		600	12.0	12.0	
T_3	77		800	25.0	18.0	
Z_1	51	Phenol resin with cellulose (paper).	600	5.0	3.5	ditto.
Z_2	54		800	8.0	5.5	
Z_3	57		1200	15.0	10.0	
K	131	Urea resin with organic filler.	600	5.0	1.2	ditto.
K*	131.5					
6	916	Nat. resin, nat. or synth. bitumen with inorg. filler.	350	3.5	3.5	ditto.
7	917		250	1.5	1.5	
8	918	Nat. or synth. bitumen with inorg. filler.	180	1.2	1.2	ditto.
A	400	Acetyl cellulose with or without filler.	300	15.0	10.0	ditto.
A*	400.5					
2	212	Synth. resin with asbestos or other inorg. filler.	350	2.0	1.5	Cold press.
3	213	ditto	200	1.7	1.2	ditto.
4	914	Nat. or synth. bitumen with asbestos or other inorg. filler.	150	1.2	1.0	ditto.
Y		Lead borate with mica.	1000	5.0	5.0	Hot press.
X		Cement or isinglass with asbestos or other inorg. filler.	150	1.5	1.5	Cold press.

150 to 199	other thermoplastics containing N_2 (*e.g.*, melamin resins).
200 to 299	cold pressed phenol resins.
300 to 399	other condensation products (*e.g.*, superpolyamides).
400 to 499	cellulose derivatives.
500 to 599	polymerisation products.
600 to 699	not used at present.
700 to 799	mixed polymerisation.
800 to 899	not used at present.
900 to 999	bitumen, natural resins.
1000 to 1999	not used at present.
2000 to 2999	laminated plastics.

The subdivision of this class of plastics is on the same lines as those of the moulded products.

Special properties are indicated by a single decimal figure following the code number. Thus .5 indicates specially high electrical qualities.

Reference to the table shows that the standard laminated products T_3 and Z_3 have been given the code numbers 77 and 57 respectively (which really belong to moulded products) instead of being included in the 2000 series. This is purely a wartime expediency

It should be pointed out that the coding of engineering materials by numbers is now being carried out quite generally in Germany and not confined to plastics.

The Strength of Internal Threads in Plastic Materials. (A. Thum and A. Boden, Z.V.D.I., Vol. 87 (1943), Nos. 31-32, pp. 506-507.) (127/8 Germany.)

The experiments covered static and fatigue strength of screwed connections of a moulded plastic nut (formaldehyde base resin) fitted to a steel bolt. The nuts (circular contour) were cut out of standard sheets, previously drilled and threaded, the thickness of the plate (height of nut) being usually three times that of the corresponding bolt diameter.

Four different types of plastic material were tested, bearing the standard designations S, Z1, Z3 and T2 respectively. These differed in the nature of the filler employed, as shown below:—

Type	*Filler*
S	wood flour.
Z1, Z3	cellulose (paper).
T2	textile fibre.

Of the above, Z3 can be regarded as properly laminated. (For mechanical properties see Abstract 127/7.)

The majority of the bolts tested were made of "automatic" steel with an ultimate tensile of about 68 kg./mm.^{2} For some of the fatigue tests, heat-treated bolts with an ultimate tensile of 80-90 kg./mm.^{2} were employed. Since in practice the tensile strength of steel and light alloy bolts engaging with internally threaded plastic parts is usually limited to 50 and 35 kg./mm.^{2} respectively, the minimum nut dimensions determined by the author should be amply sufficient.

Tensile Tests.

The minimum bolt dimensions to ensure that fracture under tensile load should occur in the bolt before stripping the thread are given in the following table:—

Type of Plastic.	Thread.	D/d	t/d
S	3 × .5	3	2
	8 × 1.25	3.5	2.5
	12 × 1.75	4	3
Z1	8 × 1.25	2.5	2.5
Z3	3 × .5	2	2
	8 × 1.25	2	2.5
	8 × 1.75	1.8	1.5
T2	3 × .5	2.5	3
	8 × 1.25	2.5	3

The threads throughout are metric, the first letter indicating the outside diameter and the second the pitch, both expresed in millimetres.

D = outside diameter of circular nut.
d = outside diameter of bolt.
t = length of bolt inside nut.

It will be noted that the nut dimensions are least for the laminated product Z3. This only holds provided the threads are cut at

right angles to the laminations, since the material between the laminations is very weak.

The homogeneous product S, on the other hand, shows no such directional effect. Some coarse fillers, however, undergo marked stratification during manufacture, and in this case care must be taken to arrange the threads correctly so that maximum strength of the nut is achieved. In case of nuts made of Z1 (short fibre cellulose filler) the difference in ultimate load amounts to 11%, and for T2 (cut up textile filler) to as much as 23%, depending on whether the threads coincide or are at right angles to the direction of extrusion.

From the point of view of bolt strength, fine threads are obviously an advantage since for the same diameter the core area is increased. This is shown in the following table for an 8 mm. steel bolt fitted with various metric threads.

Pitch (mm.)	Ultimate load (kg.)
.75	2400
1.25	2200
1.75	1900

Using the corresponding nut made of Z3 material ($D/d=2$), the breaking load of the combination is of the same order for 1.25 and 1.75 mm. pitches (*i.e.*, 2200 and 1900 kg.) provided the length of bolt inside the nut exceeds 2.5 and 1.5 d respectively (see table). With a .75 mm. pitch, however, the threads will strip before the bolt breaks, however long the nut, and the ultimate breaking load ($t/d=3$) is only 1700 kg. against the 2400 kg. of the bolt by itself.

The only practical way of achieving high ultimate loads of the bolt/nut combination is to use coarse threads and make up for the reduced core area by employing a higher grade steel for the bolt.

In the case of an al. alloy 8×1.25 mm. bolt screwed into a Z3 nut ($D/d=2$), failure occurred due to bolt fracture, provided t/d exceeded 2. The breaking load in this case was of the order of 1600 kg. against 2200 kg. for a steel bolt.

For smaller values of t, failure is due to stripping of the threads in the plastic nut, and it might be thought that in this case the breaking loads should be the same whether a steel or alloy bolt is used. As a matter of fact, the light alloy bolt combination under these conditions will strip at the nut at a load which is about 50 to 100 kg. less than if a steel bolt is used. This is shown in the following table:—

	P (kg.)	
t/d	Light alloy bolt.	Steel bolt.
.5	600 failure	650
1	1150 at	1230 failure
1.5	1550 nut	1650 at
2	1650	1950 nut
2.5	1650 bolt	2150
3	1650 fracture	2200 bolt
3.5	1650	2200 fracture

The slightly smaller stripping loads of the nut in the case of the light alloy bolt is due to the reduction in the elastic modulus of the bolt material causing higher local stresses in the threads of the nut.

Fatigue Tests.

The minimum nut dimensions as determined by static tests and given in the table above also apply to fatigue loads and ensure that ultimate failure will be due to bolt fracture in every case. It is interesting to note that under these conditions the fatigue strength of the nut/bolt combination is considerably greater than if a steel nut is fitted. In the case of Z3 material, this advantage amounts to at least 25% for soft steel bolts and reaches nearly 40% for heat-treated steel bolts. Unfortunately, all plastic materials exhibit considerable creep under load even at room temperatures, and screwed combinations employing plastic nuts are therefore incapable of maintaining appreciable pretensions. There are, however, many cases of machine elements incorporating joints of small elasticity requiring only a limited pretension of the bolt. In all such cases (*e.g.*, couplings, slides, presses, etc.) the plastic

nut/metal bolt combination has proved an outstanding success due to its high fatigue strength and freedom from corrosion and wear. The same naturally applies to the joining of plastic parts by means of internal threads and steel studs. In special cases a metal sheath can be fitted to the outside of the nut. This prevents distortion and increases the resistance of the plastic thread considerably.

The Degassing of Light Metal Alloys by Sonic Vibrations. (W. Esmarch, T. Rommel and K. Benther, W.V. Siemens Werke. Werkstoff Sonderhoft, Berlin, 1940, pp. 78-87.) (127/9 Germany.)

It is well known that the passage of an ultra sonic wave is accompanied by the formation of gas bubbles. These bubbles are partly due to the coalescence of microscopic bubbles already present in the liquid and are reinforced by previously dissolved gas being liberated in the low pressure regions of the sound wave.

Kruger in 1931 took out a patent for degassing metallic melts by this method (German Patent No. 604486), ultra sonic waves being generated in the melt by a dipper controlled by a magnetostrictive oscillator. The main difficulty in this process was the provision of suitable material for the dipper. Ceramic materials rapidly disintegrated whilst metallic dippers only proved suitable in rare instances. In addition, the process of wave generation in the melt is very inefficient, a considerable proportion of the energy of the oscillator being lost by reflexion at the surfaces of separation or absorbed by the dipper.

It appears that the only way of making the process commercially possible would be the generation of high frequency waves directly inside the melt. Now in the high frequency electric furnace the heat production is due to the formation of eddy currents in the charge. These eddy currents, moreover, are subjected to electrodynamic forces due to the magnetic field of the furnace circuit, and cause the well-known rotary motion of the melt in induction furnaces.

This rotary motion favours the absorption of air by the molten material and therefore counteracts to some extent the degassing effect of the rise in temperature.

By superimposing a steady magnetic field on the high frequency field of the furnace (the resultant field being in the direction of the coil axis) mechanical vibrations can be induced in the melt, the force at each point being proportional to the product of the local current density and field strength, and acting radially to the coil axis. Moreover, by suitable choice of bath dimensions, resonance effects can be produced which increase the intensity of the vibrations. We thus have a method of generating high frequency waves in the melt without the need of a dipper. On the other hand, the frequency range is restricted to that of the alternating current feeding the furnace.

The authors are, however, convinced from preliminary experiments that there is no advantage from the degassing point of view of employing frequencies in excess of 10,000/sec., provided that the intensity of the vibration is sufficient.

In their experiments, therefore, an A.C. generator of this frequency was employed for feeding the furnace coil, the average current consumption being of the order of 100 A. The superimposed steady magnetic field was produced by 450 A direct current fed into the same coil, the D.C. generator being protected by the insertion of suitable chokes and condensers. The total energy consumption amounted to about 15 kw., of which 10 kw. were supplied by the high frequency generator. The high D.C. wattage is largely due to the fact that a standard furnace was employed. With a specially designed heating coil the energy consumption for the steady magnetic field could have been reduced very considerably.

The experiments were carried out with 8-10 kg. melts of pure aluminium and

aluminium-magnesium alloys, the temperature being kept constant at 700°C. Samples were drawn off every ten minutes and the gas content determined by the well-known vacuum method. Photographs were also taken of the polished sections.

It appears that alloys containing even relatively large % of Mg. can be completely degassed by this method in 30-60 minutes, provided the surface of the melt is protected by a fused salt layer and that dry air or nitrogen is directed on to the surface during the treatment.

Suitable salts can be obtained from the I.G. under the trade names Hydrosal and Elrasal. A laboratory product utilised by the authors and giving equally good results has the following composition:—

K Cl	.. ..	40%
Na Cl	.. ..	30%
Ca CO_3	.. ..	15%
Na F	.. ..	15%

COMMITTEES OF COUNCIL

Amulree Committee

Professor L. Bairstow
Mr. Griffith Brewer
Sir Richard Fairey
Lord Gorell
Lord Mottistone
Lord Sempill
Mr. E. F. Relf
Mr. H. E. Wimperis

Branches Committee

Major B. W. Shilson (*Chairman*)
Mr. E. J. Archbold
Mr. A. E. Russell
Sir Francis Shelmerdine
Mr. A. G. Elliott
Mr. G. E. Petty

Education and Examinations Committee

Professor G. T. R. Hill (*Chairman*)
Dr. H. Roxbee-Cox
Mr. W. S. Farren
Professor F. T. Hill
Mr. M. Langley
Air Commodore W. M. Page
Dr. N. A. V. Piercy
Mr. W. P. Savage
Mr. R. S. Stafford
Professor L. Bairstow

Finance Committee

Mr. W. C. Devereux (*Chairman*)
Captain A. G. Lamplugh (Hon. Treasurer)
Mr. Griffith Brewer
Professor F. T. Hill
Mr. J. E. Hodgson (Hon. Librarian)
Sir Frederick Handley Page
Mr. A. D. N. Smith (Hon. Accountant)
Major B. W. Shilson
Mr. L. A. Wingfield (Solicitor)
Captain P. D. Acland

Grading Committee

Lord Sempill (*Chairman*)
Dr. H. Roxbee-Cox
Mr. E. C. Gordon England
Professor F. T. Hill
Dr. H. C. Watts
Mr. G. E. Petty
Mr. R. S. Stafford

Journal Committee

Mr. G. H. Dowty (*Chairman*)
Mr. S. Camm
Dr. H. Roxbee-Cox
Major R. H. Mayo
Mr. W. C. Devereux

Lectures Committee

Mr. S. Camm (*Chairman*)
Professor L. Bairstow
Major G. P. Bulman
Dr. H. Roxbee-Cox
Major R. H. Mayo
Mr. S. Scott-Hall
Mr. C. C. Walker
Mr. D. L. Ellis
Mr. R. T. Youngman
Sir A. H. Roy Fedden
Mr. N. E. Rowe
Mr. G. H. Dowty

Lecture Hall Committee

Professor L. Bairstow
Major B. W. Shilson
Sir A. H. Roy Fedden
Mr. W. C. Devereux

Medals and Awards Committee

Professor G. T. R. Hill (*Chairman*)
Mr. Griffith Brewer
Sir A. H. Roy Fedden
Mr. A. Gouge
Lieut.-Col. W. Lockwood Marsh
Mr. G. R. Volkert
Mr. C. C. Walker
Mr. L. A. Wingfield (Solicitor)
Professor A. J. Sutton Pippard
Mr. H. E. Wimperis
Professor L. Bairstow

Rules Committee

Professor L. Bairstow (*Chairman*)
Mr. S. Camm
Captain P. D. Acland
Mr. Griffith Brewer
Mr. H. E. Wimperis

Social Functions Committee

Mr. A. Gouge
Sir A. H. Roy Fedden
Major R. H. Mayo
Mr. R. K. Pierson

Garden Party Committee

Sir A. H. Roy Fedden
Major R. H. Mayo
Mr. R. K. Pierson

Technical Staff Committee

Mr. W. C. Devereux (*Chairman*)
Mr. A. Gouge
Major R. H. Mayo
Mr. R. K. Pierson
Sir Roy A. H. Fedden
Dr. H. Roxbee-Cox

THE SOCIETY'S PRIZES

The Society offers a number of valuable prizes, most of them annually. Full particulars of the conditions attaching to the awards of these prizes may be obtained on application

Society's Gold Medal

This is the highest honour which the Society can confer for work of an outstanding or fundamental nature in aeronautics.

British Gold Medal for Aeronautics

The British Gold Medal for Aeronautics is awarded for an achievement leading to advancement in aeronautical science.

Simms Gold Medal

The Simms Gold Medal is awarded annually for the best paper read in any year before the Society on any science allied to aeronautics, e.g., meteorology, wireless telegraphy, instruments.

The George Taylor (of Australia) Gold Medal

The Taylor Gold Medal is awarded annually, at the discretion of the Council, for the most valuable paper submitted or read during the previous session.

Wakefield Gold Medal

The Wakefield Gold Medal is awarded annually to the designer of any invention or apparatus tending towards safety in flying, and is open to members or non-members.

Society's Silver Medal

The Society's Silver Medal is awarded, at the discretion of the Council, for some advance in aeronautical design.

British Silver Medal for Aeronautics

The British Silver Medal for Aeronautics is awarded for an achievement leading to advancement in aeronautical science.

Society's Bronze Medal

The Society's Bronze Medal is awarded, at the discretion of the Council, under the same conditions as those for the Silver Medal, but for some less important advance in aeronautical design.

Wilbur Wright Memorial Premium

The Wilbur Wright Memorial Lecture is held annually, a premium of fifty pounds being awarded to the lecturer invited by the Council to deliver the lecture. The lecture is usually given alternately by an American and an Englishman, and is the most important aeronautical lecture of the year. It is delivered whenever possible, on the last Thursday in May of each year.

British Empire Lecture

The Council of the Royal Aeronautical Society have completed the arrangements for the founding of a British Empire Lecture.

The lecture, on any aeronautical subject approved by the Council, will be delivered annually in September in London, by a lecturer, chosen in alternate years from the British Dominions and Colonies and Great Britain.

The Council, by founding this British

Empire Lecture, are anxious to encourage new ideas and new points of view from all parts of the British Empire, and to make the Lecture second only in importance to the Wilbur Wright Memorial Lecture.

The British Empire Lecture will have a premium of £50 attached to it, and in the case of lecturers coming from the Dominions and Colonies an allowance up to £100 will be paid towards the Lecturer's expenses.

It is proposed to hold the first lecture in September, 1945, and suggestions for lecturers should be received by May 31st, 1945, at the latest.

R.38 Memorial Prize

The R.38 Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in the science of aeronautics, preference being given to papers which relate to airships. The prize is twenty-five guineas.

The Herbert Akroyd Stuart Lectures

Under the will of the late Mr. Herbert Akroyd Stuart a sum of £700 is held in trust by the Society for the offer of a prize every two years, for the best paper or lecture read or given before the Society dealing with the Origin and Development of Heavy-oil Aero Engines. The prize is open to members and non-members.

Edward Busk Memorial Prize

The Edward Busk Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in connection with aeroplanes (including seaplanes). Its value is twenty guineas.

Pilcher Memorial Prize

The Pilcher Memorial Prize is offered annually, at the discretion of the Council, for the best paper by a Student on heavier-than-air craft or any analogous subject. Its value is five guineas.

Usborne Prize

The Usborne Prize is offered annually, at the discretion of the Council, for the best paper by a Student on some subject in connection with Aero Engines. Its value is five guineas.

Major Baden-Powell Memorial Prize

The Major Baden-Powell Memorial Prize is awarded in May and December of each year to the student who is considered the best student by the examiners in the Society's Association Fellowship examinations. Its value is three guineas.

Elliott Memorial Prize

The Elliott Memorial Prize is awarded twice yearly to the apprentice at Halton who has the highest percentage of marks in the passing-out examination. Its value is 2½ guineas for each award.

R. P. Alston Memorial Prize

The R. P. Alston Memorial Prize is awarded to any Graduate or Student of the Society for work done leading to improvement in the safety of aircraft, and particularly for improvement in stability and control. Its value is approximately £5.

Branch Prize

The Council offer an annual prize of twenty guineas for the best paper read before the Branches during the previous lecture Session. The prize is open to any member of the Society or of any Branch.

Journal Premium Awards

The Council has set aside an annual sum of £250 to be given as premium awards to authors of papers published in the Journal.

AN APPRECIATION

The Council of the Royal Aeronautical Society wish to thank the following Companies who, by their generous co-operation, have done so much to help in the production of the Journal in its new form.

THE HUGHES-JOHNSON STAMPINGS LTD.

INTERNATIONAL ALLOYS LIMITED

HUNTING AVIATION LIMITED
(formerly Necaco Ltd.)

IRVING AIR CHUTE OF GREAT BRITAIN LTD.

IMPERIAL CHEMICAL INDUSTRIES
(METALS) LIMITED

JABLO PROPELLERS LIMITED

INTEGRAL LTD.

WALTER W. JENKINS & CO., LTD.

MANUFACTURERS OF HYDRAULIC AND ELECTRICAL EQUIPMENT

K.D.G. INSTRUMENTS LTD.

ARTHUR LEE & SONS, LTD.

KELVIN BOTTOMLEY & BAIRD LTD.

LEYTONSTONE JIG & TOOL CO., LTD.

K.L.G. SPARKING PLUGS LTD.

LIGHT-METAL FORGINGS LTD.

KODAK LIMITED

LODGE PLUGS LIMITED

LANGLEY ALLOYS LTD.

THE LONDON NAME PLATE MANUFACTURING CO., LTD.

MACROME LTD.

MACROME

"THE TOUGHEST TOOLS IN THE WORLD."

MILES AIRCRAFT LIMITED

Miles
AIRCRAFT

MAGNESIUM CASTINGS & PRODUCTS LTD.

HENRY MILLER & COMPANY

SKYHI

MARSTON EXCELSIOR LIMITED

MAREX

MOLLART ENGINEERING COMPANY LTD.

ME

MESSIER AIRCRAFT EQUIPMENT LIMITED

MESSIER

THE MOND NICKEL COMPANY LTD.

NICKEL

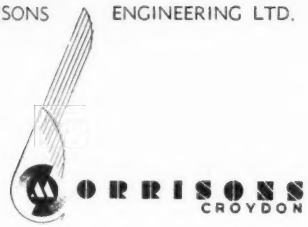
METALASTIK LIMITED

METALASTIK
RUBBER-TO-METAL WELD

MONOCHROME LIMITED

MONOCHROME

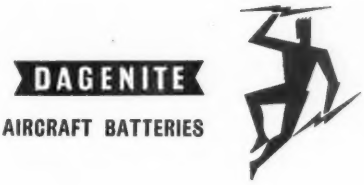
MORRISONS ENGINEERING LTD.



PERCIVAL AIRCRAFT LIMITED

D. NAPIER & SON LIMITED

PETO & RADFORD



NITRALLOY LIMITED

PHILIDAS LIMITED

THE PALMER TYRE LIMITED

SIR ISAAC PITMAN & SONS LIMITED

PARNALL AIRCRAFT LIMITED

PRESSED STEEL CO., LTD.

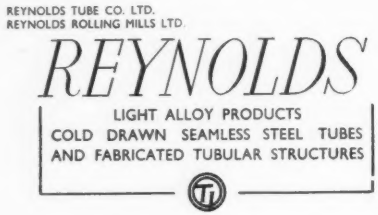
PYE LIMITED

ROLLS-ROYCE LIMITED

RANSOMES, SIMS & JEFFERIES LTD.

S. GRAHAME ROSS LTD.

REYNOLDS TUBE CO., LTD.



ROTAX LTD.

R.F.D. COMPANY LTD.

ROTOL LIMITED

A. V. ROE & COMPANY, LIMITED

L. A. RUMBOLD & CO., LTD.

SANGAMO WESTON LTD.

SIMMS MOTOR UNITS LTD.

SAUNDERS-ROE LTD.

SMITHS AIRCRAFT INSTRUMENTS LTD.

SMITHS AIRCRAFT
INSTRUMENTS LTD

SERCK RADIATORS LIMITED

SERCK

THE SPERRY GYROSCOPE COMPANY LTD.

SHORT BROTHERS (ROCHESTER & BEDFORD) LIMITED

SHORT BROTHERS
(Rochester & Bedford) Ltd.

M. E. STACE & CO., LTD.

SIMMONDS AEROCESSORIES LTD.

STANDARD TELEPHONES & CABLES LTD.

Standard
Radio

TAYLORCRAFT AEROPLANES (ENGLAND) LIMITED

THE STEEL TAYLORCRAFT AUSTER AEROPLANE
THE EYES OF THE ARMY

TURNER MANUFACTURING COMPANY LIMITED

TURNER
MANUFACTURING COMPANY LIMITED

THE TECHNOLOGICAL INSTITUTE OF GREAT BRITAIN

TI
WORLD'S BEST CHOICE OF COURSES IN AERONAUTICAL ENGINEERING

THE UNITED STEEL COMPANIES LIMITED

"FLYING FOX"
ELECTRIC STEELS
S. FOX & CO. LTD. SHEFFIELD

TITANINE LIMITED

TITANINE
DOPE

VICKERS-ARMSTRONGS LIMITED

TUBES LIMITED

tubes limited

VOKES LTD.

VOKES

ERNEST TURNER GROUP

Ernest Turner (London), Ltd.
Ernest Turner (Weaving), Ltd.
Ernest Turner Electrical Instruments, Ltd.
Chas. Dould & Son, Ltd.

TRADE MARK
REGISTERED

WADKIN LTD.

Wadkin

WARWICK AVIATION COMPANY LTD.

WILKINSON RUBBER LINATEX LTD.

WESTLAND AIRCRAFT LIMITED

WILLIAMSON MANUFACTURING CO., LTD.

CHAS. WESTON & CO., LTD.

WORCESTER WINDSHIELDS AND CASEMENTS LIMITED

A. C. WICKMAN LIMITED

YORKSHIRE ENGINEERING SUPPLIES LTD.

HENRY WIGGIN & COMPANY LTD.

THE YORKSHIRE PATENT STEAM WAGON CO.

DIRECTORY OF ADVERTISERS

Accles & Pollock Ltd.	Paddock Works, Oldbury, Birmingham	*Broadwell* 1500
AC-Sphinx Sparking Plug Co. Ltd.	Dunstable, Beds.	*Dunstable* 360
Aeraspray Mfg. Co. Ltd.	Thimble Mill Lane, Birmingham, 7	*Birmingham East* 1671 (*all lines*)
"The Aeroplane"	Bowling Green Lane, London, E.C.1	*Terminus* 3636
Aeroplane & Motor Aluminium Castings Ltd.	Wood Lane, Erdington, Birmingham	*Erdington* 2207-8-9
Airspeed Limited	The Airport, Portsmouth	*Portsmouth* 74631 (8 *lines*)
Alvis Limited	Holyhead Road, Coventry	*Coventry* 5501
Geo. Angus & Co. Ltd.	Angus House, 152-158 Westgate Road, Newcastle-upon-Tyne, 1	*Newcastle-upon-Tyne* 22656 (4 *lines*)
Armstrong Siddeley Motors Limited	Parkside, Coventry	*Coventry* 4061
W. G. Armstrong Whitworth Aircraft Ltd.	Whitley, Coventry	*Coventry* 61061-4
The Automatic Coil Winder & Electrical Equipment Co. Ltd.	Winder House, Douglas Street, London, S.W.1	*Victoria* 3404-8 (5 *lines*)
Automotive Products Company Ltd.	Tachbrook Road, Leamington Spa	*Leamington Spa* 1700
Avimo Ltd.	Taunton, Somerset	*Taunton* 3634
Bakelite Limited	18 Grosvenor Gardens, London, S.W.1	*Sloane* 9911
Bell Punch Co. Ltd.	36 St. James's Street, London, S.W.1	*Regent* 1532 (5 *lines*)
	Factories: Uxbridge, Middlesex	*Uxbridge* 1111
T. M. Birkett & Sons Ltd.	Thomas Street, Hanley, Stoke-on-Trent	*Stoke-on-Trent* 2184
Birmingham Aluminium Casting (1903) Co. Ltd.	Smethwick, Birmingham, 40	*Smethwick* 1431 (12 *lines*)
Blackburn Aircraft Ltd.	Brough, E. Yorks.	*Brough* 121
James Booth & Company Ltd.	Argyle Street Works, Nechells, Birmingham, 7	*Birmingham East* 1221
Boulton Paul Aircraft Ltd.	Wolverhampton, Staffs.	*Fordhouses* 3191
The Bristol Aeroplane Company Ltd.	Filton House, Bristol	
British Aluminium Co. Ltd., The	Salisbury House, London Wall, London, E.C.2	*Clerkenwell* 3494
The British Aviation Insurance Company Ltd.	3-4 Lime Street, London, E.C.3	*Mansion House* 0444 (6 *lines*)
British Ermeto Corporation Ltd.	Beacon Works, Hargrave Road, Maidenhead, Berks.	*Maidenhead* 2271
The British Parachute Company Ltd.	Trinity Street, Cardiff	*Cardiff* 8735-6-7
British Ropes Limited	52 High Holborn, London, W.C.1	*Chancery* 8822
The British Thomson-Houston Co. Ltd.	Crown House, Aldwych, London, W.C.2	*Temple Bar* 8040
British Wire Products Ltd.	Worcester Road, Stourport-on-Severn	*Stourport* 240
The Brooke Tool Manufacturing Co. Ltd.	Warwick Road, Greet, Birmingham, 11	*Birmingham Victoria* 2323 (10 lines)
Broom & Wade Ltd.	High Wycombe, Bucks.	*High Wycombe* 1630 (8 *lines*)
Brown Brothers (Aircraft) Ltd.	Great Eastern Street, London, E.C.2	*Bishopsgate* 7654 (33 lines)

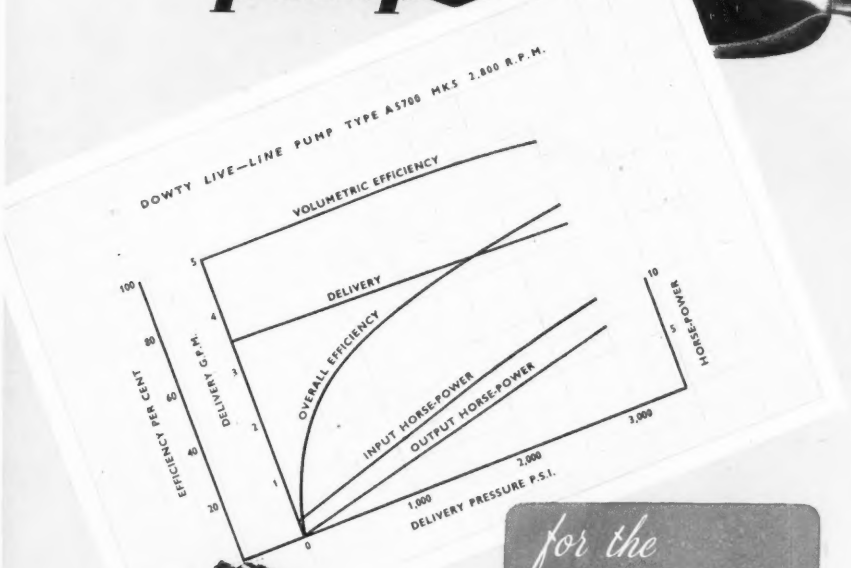
DAVID BROWN & SONS (HUDDERSFIELD) LTD.	Huddersfield	*Huddersfield* 3500 (7 *lines*)
THE BUSHING COMPANY LIMITED	Head Office: Hebburn-on-Tyne	*Hebburn* 32241
	London Office: Imperial House, Kingsway, W.C.2	*Temple Bar* 9584
BUTLERS LIMITED	Atlantic Works, Grange Road, Small Heath, Birmingham, 10	*Victoria* 2164-5-6
THE CHLORIDE ELECTRICAL STORAGE CO. LTD.	Exide Works, Clifton Junction, near Manchester	*Swinton* 2011
THE CLYDE ALLOY STEEL COMPANY LTD.	Craigneuk Works, Motherwell, Lanarkshire	*Motherwell* 1051 (6 *lines*)
COOPER & CO. (B'HAM) LTD.	53 Little King Street, Birmingham, 19	*Northern* 2194-5
CROWN WELDING CO. LTD.	Castle Hill, Douglas, Isle of Man	*Douglas* 199
THE DE HAVILLAND AIRCRAFT CO. LIMITED	Hatfield Aerodrome, Herts.	*Hatfield* 2345
DE LA RUE INSULATION LTD.	Imperial House, 84 Regent Street, London, W.1	*Regent* 2901
DE LA RUE PLASTICS LTD.	Imperial House, 84 Regent Street, London, W.1	*Regent* 2901
DELCO-REMY & HYATT LTD.	111 Grosvenor Road, S.W.1	*Victoria* 6242 (7 *lines*)
DOWTY EQUIPMENT LIMITED	Arle Court, Cheltenham, Glos.	*Cheltenham* 53471
DUNFORD & ELLIOTT (SHEFFIELD) LTD.	Attercliffe Wharf Works, Sheffield, 9	*Sheffield* 41121-2-3-4
DUNLOP RUBBER CO. LTD.	Fort Dunlop, Erdington, Birmingham, 24.	*Erdington* 2121
THE FAIREY AVIATION COMPANY LTD.	Hayes, Middlesex.	*Hayes* 400
FERODO LIMITED	Chapel-en-le-Frith, Stockport.	*Chapel-en-le-Frith* 250
THOS. FIRTH & JOHN BROWN LTD.	Atlas & Norfolk Works, Sheffield, 1.	*Sheffield* 20081 (10 *lines*) 26491 (6 *lines*)
FIRTH-VICKERS STAINLESS STEELS LTD.	Staybrite Works, Sheffield	*Sheffield* 41193
FLIGHT PUBLISHING CO. LTD.	Dorset House, Stamford Street, London, S.E.1	*Waterloo* 3333
FLIGHT REFUELLING LIMITED	Pickersleigh Road, Malvern Link, Worcs.	*Malvern* 1481
FOLLAND AIRCRAFT LTD.	Hamble, Southampton, Hants.	*Hamble* 3191
GILLETT STEPHEN & CO. LTD.	Atlas Works, Great Bookham, Leatherhead, Surrey	*Bookham* 2727 (4 *lines*)
GIRLING LIMITED	Garrison Lane, Birmingham, 9	*Victoria* 2951
GLOSTER AIRCRAFT CO. LTD.	Gloster Works and Aerodrome, Hucclecote, Glos.	*Gloucester* 6294 (18 *lines*)
GRAVINER MANUFACTURING COMPANY LTD.	16 Bassett Gardens, Osterley, Isleworth, Middlesex	*Hounslow* 1218
	Fleetlands Foundry, Gosport Road, near Fareham, Hants.	*Gosport* 89175-6-7
HANDLEY PAGE LTD.	Cricklewood, London, N.W.2	*Gladstone* 8000
HAWKER AIRCRAFT LTD.	Canbury Park Road, Kingston-on-Thames	*Kingston* 1044 *Slough* 23861
HEALTHGUARD AEROQUIPMENT	Woodbridge Road, Leicester.	*Leicester* 61228

HELLIWELLS LTD.	Old Town, Stratford-on-Avon	*Stratford-on-Avon* 3265
THE HESTON AIRCRAFT CO. LTD.	Heston Airport, Middlesex	*Southall* 2321
HEYWOOD COMPRESSOR CO. LTD.	Glover Street, Redditch, Worcs.	*Redditch* 743
HIDUMINIUM APPLICATIONS LTD.	95 Farnham Road, Slough, Bucks.	*Slough* 20409
HIGH DUTY ALLOYS LTD.	89 Buckingham Avenue, Slough, Bucks.	*Slough* 21201
H. M. HOBSON (AIRCRAFT & MOTOR) COMPONENTS LTD.	Hobson Works, Holbrook Lane, Coventry	*Coventry* 88671 (3 *lines*)
S. HUBBARD LIMITED	Regent Mill, Luton, Beds.	*Luton* 2076
F. A. HUGHES & CO. LTD.	Lumm's Lane, Clifton Junction, Swinton, near Manchester.	*Swinton* 2511
HENRY HUGHES & SON LTD.	Husun Works, New North Road, Barkingside, Essex	*Hainault* 2601
THE HUGHES-JOHNSON STAMPINGS LTD.	Langley Green, Birmingham	*Broadwell* 1361 (3 *lines*)
HUNTING AVIATION LIMITED	P.O. Box 4, Caernarvon, N. Wales	*Caernarvon* 580 (4 *lines*)
I.C.I. (METALS) LTD.	Kynoch Works, Witton, Birmingham, 6	*Birchfields* 4848
INTEGRAL LTD.	Power Road, Chiswick, London, W.5	*Chiswick* 1539 *Chiswick* 3323
INTERNATIONAL ALLOYS LIMITED	Buckingham Avenue, Trading Estate, Slough, Bucks.	*Slough* 23212
IRVING AIR CHUTE OF GREAT BRITAIN LTD.	Icknield Way, Letchworth, Herts.	*Letchworth* 888
JABLO PROPELLERS LIMITED	Mill Lane, Waddon, Croydon, Surrey	*Croydon* 2201 (4 *lines*)
WALTER W. JENKINS & CO. LTD.	31 St. Paul's Street North, Cheltenham	*Cheltenham* 53254
K.D.G. INSTRUMENTS LTD.	Purley Way, Croydon, Surrey	*Thornton Heath* 3868
KELVIN, BOTTOMLEY & BAIRD LTD.	18 Kelvin Avenue, Hillington, Glasgow	*Halfway* 1661
K.L.G. SPARKING PLUGS LTD.	Putney Vale, London, S.W.15	*Putney* 2671 (4 *lines*)
KODAK LIMITED	Kodak House, Kingsway, London, W.C.2	*Holborn* 7841
LANGLEY ALLOYS LTD.	Langley, Slough, Bucks.	*Langley* 262-3
ARTHUR LEE & SONS LTD.	Crown Steel and Wire Mills, Bessemer Road, Sheffield, 9	*Attercliffe* 41144-5-6-7-8
	Mowbray House, Norfolk Street, London, W.C.2	*Temple Bar* 7187-8
	155 Church Lane, Handsworth Road, Birmingham, 20	*Northern* 2116-7
LEYTONSTONE JIG & TOOL CO. LTD.	606 High Road, Leyton, London, E.10	*Leytonstone* 5022-3
LIGHT-METAL FORGINGS LTD.	Oldbury, Birmingham	*Broadwell* 1152
LODGE PLUGS LIMITED	Rugby	*Rugby* 2076 (2 *lines*)
THE LONDON NAME PLATE MANUFACTURING CO. LTD.	Zylo Works, Marine View, Brighton, 7	*Brighton* 7025 (5 *lines*)
MACHROME LTD.	Alcester, Warwickshire	*Alcester* 191-2-3
MAGNESIUM CASTINGS AND PRODUCTS LTD.	89 Buckingham Avenue, Trading Estate, Slough	*Slough* 20207
MARSTON EXCELSIOR LIMITED	Wolverhampton	*Wolverhampton* 21481
	49-59 Armley Road, Leeds, 12	*Armley* 38081-5

Messier Aircraft Equipment Limited	Liverpool Road, Warrington	*Warrington* 2244
Metalastik Limited	Evington Valley Road, Leicester	*Leicester* 25196
Miles Aircraft Limited	Reading, Berkshire	*Reading* 60811
Henry Miller & Company	"Skyhi" Works, Standard Road, Park Royal, London, N.W.10	*Willesden* 1302-3-4
Mollart Engineering Company Ltd.	Kingston By-Pass, Surbiton, Surrey	*Elmbridge* 3352-3-4 (3 *lines*)
The Mond Nickel Company Ltd.	Grosvenor House, Park Lane, London, W.1	*Grosvenor* 4131
Monochrome Limited	Studley Road, Redditch, Worcs.	*Studley* 121-2
Morrisons Engineering Ltd.	Purley Way, Croydon	*Croydon* 0191
D. Napier & Son Limited	Acton, London, W.3	*Shepherds Bush* 1220
Nitralloy Limited	47 Bank Street, Sheffield, 1	*Sheffield* 25907
The Palmer Tyre Ltd.	Herga House, Vincent Square, London, S.W.1	*Victoria* 8323 (6 *lines*)
Parnall Aircraft Limited	8 South Street, Park Lane, London, W.1	*Grosvenor* 2771-2
Percival Aircraft Limited	Luton Airport, Luton, Beds.	*Luton* 2960
Peto & Radford	Chequers Lane, Dagenham, Essex	*Rainham* 34
Philidas Limited	The Aerodrome, Reading, Berkshire	*Wargrave* 218
Sir Isaac Pitman & Sons Limited	Parker Street, Kingsway, London, W.C.2	*Holborn* 9791 (4 *lines*)
Pressed Steel Co. Ltd.	Cowley, Oxford	*Oxford* 77701
Pye Limited	Radio Works, Cambridge	*Cambridge* 3434
Ransomes, Sims & Jefferies Ltd.	Orwell Works, Ipswich	*Ipswich* 2201
Reynolds Tube Co. Ltd.	Hay Hall Works, Tyseley, Birmingham	*Acocks Green* 1607
R.F.D. Company Ltd.	Stoke Road, Guildford, Surrey	*Guildford* 3232
A. V. Roe & Company Limited	Newton Heath, Manchester	*Failsworth* 2020
Rolls-Royce Ltd.	Derby	*Derby* 2424
S. Grahame Ross Ltd.	Bath Road, Slough, Bucks.	*Burnham* 686-8
Rotax Ltd.	Willesden Junction, London, N.W.10	*Willesden* 2480
Rotol Limited	Cheltenham Road, Gloucester	*Gloucester* 4431
L. A. Rumbold & Co. Ltd.	Kingsgate Place, Kilburn, London, N.W.6	*Maida Vale* 7366-7-8
Sangamo Weston Ltd.	Great Cambridge Road, Enfield, Middlesex	*Enfield* 3434 and 1242
Saunders-Roe Ltd.	49 Parliament Street, Westminster, London, S.W.1	*Whitehall* 7271
Serck Radiators Limited	Warwick Road, Birmingham, 11	*Victoria* 0531
Short Brothers (Rochester & Bedford) Ltd.	Rochester, Kent	
Simmonds Aerocessories Ltd.	Great West Road, Brentford, London	*Ealing* 2212 (18 *lines*)
Simms Motor Units Ltd.	Oak Lane, East Finchley, London, N.2	*Finchley* 2262
Smiths Aircraft Instruments Ltd.	Cricklewood Works, London, N.W.3	*Gladstone* 3333
The Sperry Gyroscope Co. Ltd.	Great West Road, Brentford, Middlesex	*Ealing* 6771 (10 *lines*)
M. E. Stace & Co. Ltd.	14 Portland Street, Cheltenham	*Cheltenham* 52021-2
Standard Telephones & Cables Ltd.	New Southgate, London, N.11	*Enterprise* 1234

Taylorcraft Aeroplanes (England) Ltd.	Britannia Works, Thurmaston, Leicester	*Syston* 86106-8
The Technological Institute of Great Britain	39 Temple Bar House, Fleet Street, London, E.C.4	*Central* 5940
Titanine Limited	Colindale, London, N.W.9	*Colindale* 8123 (6 *lines*)
Tubes Limited	Rocky Lane, Aston, Birmingham, 6	*Aston Cross* 3030
Ernest Turner Group Ernest Turner (London) Ltd. Ernest Turner (Weaving) Ltd. Ernest Turner Electrical Instruments Ltd. Chas. Dould & Son Ltd.	Northdown House, Northdown Street, King's Cross, London, N.1	*Terminus* 6674-5-6
Turner Manufacturing Co. Ltd.	Wulfruna Works, Moorfield Road, Wolverhampton	*Wolverhampton* 24456 (5 *lines*)
The United Steel Companies Limited	17 Westbourne Road, Sheffield, 10	*Sheffield* 60081 (7 *lines*)
Vickers-Armstrongs Limited (Aircraft Section)	Vickers House, Broadway, Westminster, London, S.W.1	*Abbey* 7777
Vokes Ltd.	Weybridge Works, Weybridge, Surrey Putney, S.W.15	*Byfleet* 240-243
Wadkin Ltd.	Green Lane Works, Leicester	*Leicester* 27114 (4 *lines*) 28021 (3 *lines*)
Warwick Aviation Company Ltd.	Warwick	*Warwick* 693
Westland Aircraft Limited	Yeovil	*Yeovil* 1100
Chas. Weston & Co. Ltd.	Torrington Avenue, Coventry	*Tilehill* 66291-2
A. C. Wickman Limited	Tile Hill, Coventry	*Tile Hill* 66271
Henry Wiggin & Company Ltd.	Wiggin Street, Birmingham	*Edgbaston* 2245
Wilkinson Rubber Linatex Ltd.	Frimley Road, Camberley, Surrey	*Camberley* 1595
Williamson Manufacturing Co. Ltd.	Litchfield Gardens, Willesden Green, London, N.W.10	*Willesden* 0073-0075
Worcester Windshields and Casements Ltd.	St. John's, Worcester	*Worcester* 4344 (5 *lines*)
Yorkshire Engineering Supplies Ltd.	Upper Wortley, Wortley, Leeds, 12	*Leeds* 38234 *and* 38291
The Yorkshire Patent Steam Wagon Co.	Hunslet, Leeds, 10	*Leeds* 76551 (2 *lines*)

DOWTY LIVE-LINE pump



for the **3,000 p.s.i. HYDRAULIC SYSTEM**

The **DOWTY LIVE-LINE PUMP** is pre-eminent for hydraulic systems operating at pressures up to 3,000 p.s.i. Fully automatic, it gives constant delivery up to the reaction point and thereafter acts as a variable delivery pump at constant pressure.

The pump weighs only 10 lbs. and combines the functions of cut-outs, pressure regulators and accumulators with absolute reliability of operation. This results in important weight-saving and a simplified system.

A range of pumps offering widely varying operating speeds, pressures and displacements is available for present and post-war applications.

DOWTY EQUIPMENT LIMITED, CHELTENHAM, ENGLAND

INTRODUCING TWO TEXTBOOKS ON MAGNESIUM & ITS ALLOYS

(DETAILS ON REQUEST)

1941—

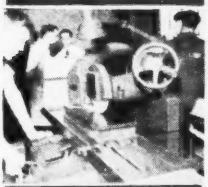
AND NOW!

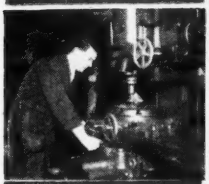
ELEKTRON
the pioneer
MAGNESIUM ALLOYS

PRICE :
METALLOGRAPHY 15/- Net
plus 6d. postage U.K.
TECHNOLOGY - 30/- Net
plus 7d. postage U.K.
Cheques to be made out to
F. A. HUGHES & CO., LTD.

● *Sole Producers and Proprietors of the Trade Mark "Elektron"* MAGNESIUM ELEKTRON LIMITED, Abbey House, London, N.W.1 ● *Licensed Manufacturers*: Castings & Forgings: STERLING METALS LIMITED, Northfield Road, Foleshill, Coventry ● Castings: THE BIRMINGHAM ALUMINIUM CASTINGS (1903) COMPANY LIMITED, Bromford Works, Smethwick, Birmingham ● J. STONE & COMPANY LIMITED, Deptford, London, S.E.14 ● Sheet, Extrusions, Forgings & Tubes: JAMES BOOTH & CO. LIMITED, Argyle Street Works, Nechells, Birmingham, 7. ● Sheet, Extrusions, Etc.: BIRMETALS LIMITED, Woodgate, Quinton, Birmingham ● Suppliers of Magnesium and Elektron Metal for the British Empire: F. A. HUGHES & CO. LIMITED, Abbey House, Baker Street, London, N.W.1

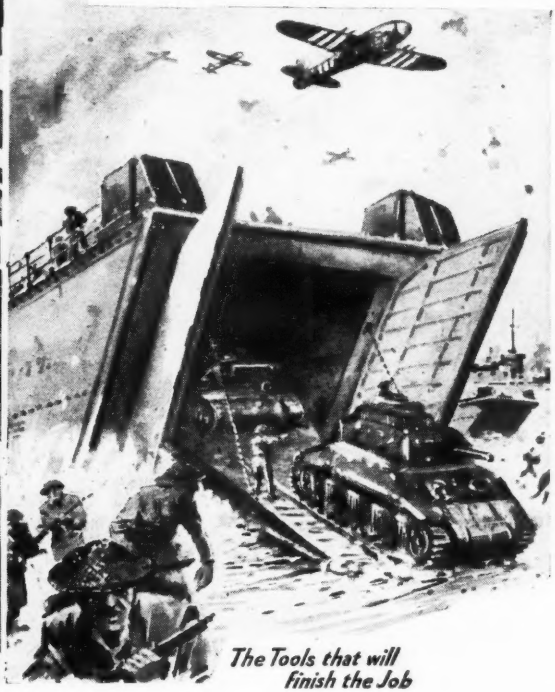
DESIGNING


GRINDING


MILLING

JIG BORING

PRODUCTION for VICTORY



The Tools that will finish the Job

Specialists in

JIGS AND FIXTURES

PRESS TOOLS

AIRCRAFT ASSEMBLY JIGS AND REFERENCE GAUGES

CAPSTAN LATHE WORK

HEAT TREATMENT

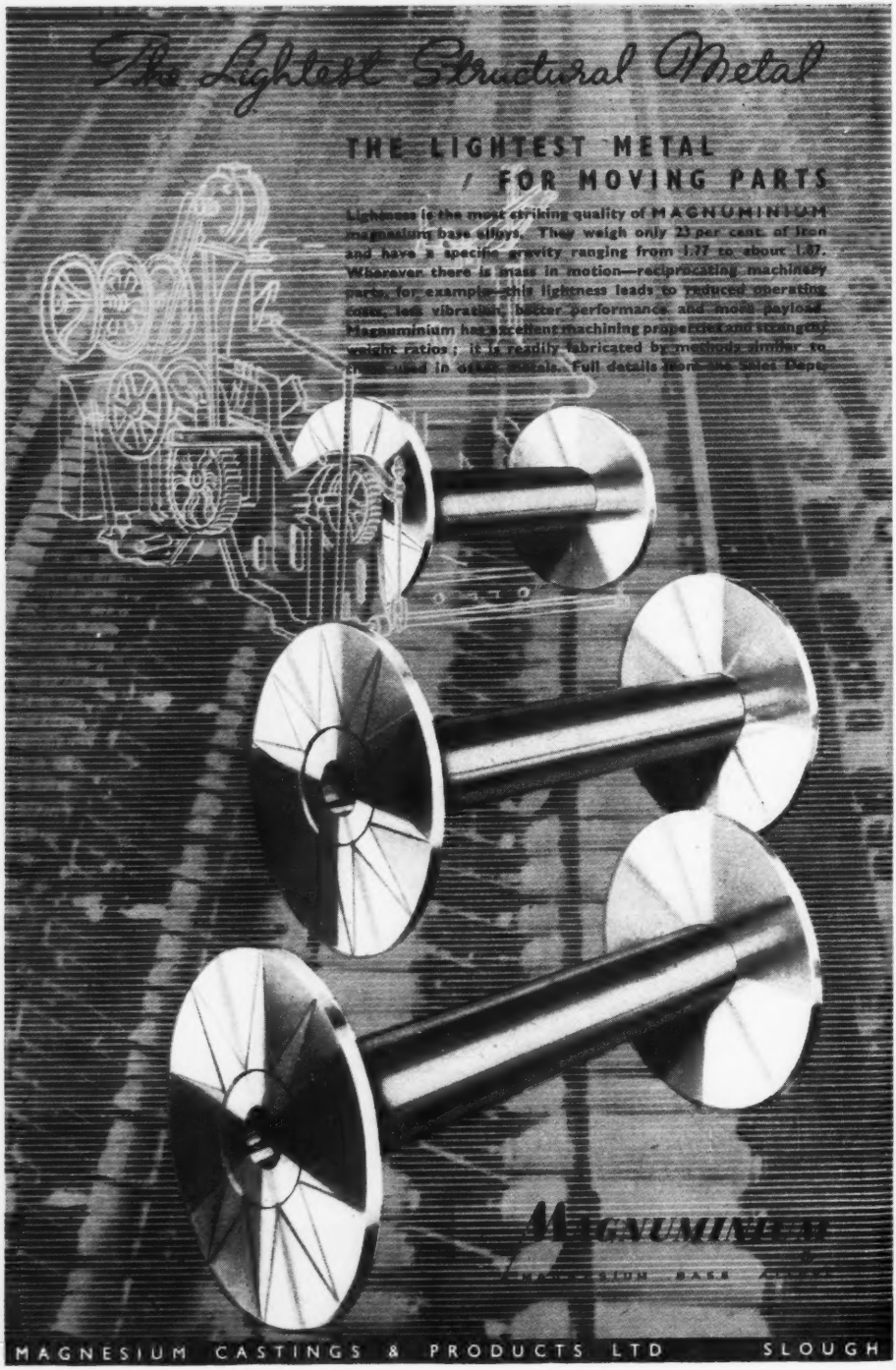
SMALL ASSEMBLY HAND TOOLS

FULLY A.I.D APPROVED

Leytonstone

JIG & TOOL Co. Ltd.

606 HIGH ROAD, LEYTON, LONDON, E.10. PHONE: LEYTONSTONE 5022-3 GRAMS: LEYTOOL, LEYSTONE


The Lightest Structural Metal
THE LIGHTEST METAL
FOR MOVING PARTS
Lightness is the most striking quality of MAGNUMINIUM magnesium base alloys. They weigh only 23 per cent. of Iron and have a specific gravity ranging from 1.77 to about 1.87. Wherever there is mass in motion—reciprocating machinery parts, for example—this lightness leads to reduced operating costs, less vibration, better performance and more payload. Magnuminium has excellent machining properties and strength/weight ratios; it is readily fabricated by methods similar to those used in other metals. Full details from the Sales Dept.
MAGNUMINIUM
MAGNESIUM CASTINGS & PRODUCTS LTD SLOUGH

From *War* to *Peace!*

AFTER five years of War, of constant endeavour under the stimulus of "Front Line" conditions, **"Standard Radio"** can look back on a period of stress and strain, of difficulties surmounted, of technical problems solved by intensive thought and inventive genius. A troublous but nevertheless valuable period of adjustment and growth under new conditions.

But more valuable still has been the experience gained by close technical collaboration with all the Services. A vital and practical experience, which will place **"Standard Radio"** engineers in the forefront as consultants and advisers in the Peacetime technical and manufacturing requirements of Aircraft Radio Communication and Navigation, the ultimate object being, as always—

A HAPPY LANDING!

STANDARD TELEPHONES AND CABLES LIMITED, NEW SOUTHGATE, LONDON N.11

Printed by the Lewes Press (Wightman & Co., Ltd.), Friars Walk, Lewes, England, and Published by the Royal Aeronautical Society, 4, Hamilton Place, London, W.1, England.